ABSTRACT OF THE DISCLOSURE

An omnidirectional drive for a Foucault pendulum is described in which a magnet swinging with the pendulum is magnetically attracted toward the rest position of the pendulum on each swing thereof as the pendulum approaches its rest position. Repelling forces are thereby avoided preventing an elliptical swing of the pendulum.

This invention relates to pendulum drive apparatus and more particularly to an omnidirectional drive for a Foucault pendulum.

Among the several objects of the present invention may be noted the provision of pendulum drive apparatus which will maintain the motion of a pendulum without introducing or reinforcing components of motion transverse to the pendulum's plane of swing which would produce an elliptical pattern of motion; the provision of such apparatus which will so maintain the motion of a pendulum which is free to swing in any vertical plane passing through its pivot; the provision of such apparatus which will regulate the amplitude of the pendulum's swing; the provision of such drive apparatus which employs no moving parts; the provision of such apparatus which is highly reliable; the provision of such apparatus which is relatively simple and inexpensive; and the provision of a novel method of driving such a pendulum. Other objects and features will be in part apparent and in part pointed out hereinafter.

The invention accordingly comprises the apparatus and methods hereinafter described, the scope of the invention being indicated in the following claims.

In the accompanying drawing in which one of various possible embodiments of the invention is illustrated, there is shown a Foucault pendulum system including electromagnetic drive apparatus for maintaining the swinging motion of the pendulum.

Corresponding reference characters indicate corresponding parts throughout the drawing.

Referring now to the drawing there is indicated at 11 a Foucault pendulum of the type commonly employed in planetariums, museums of science and the like for illustrating the earth's rotation. In order to minimize the effects of extraneous forces, the pendulum 11 preferably includes a bob 13 which is as heavy as is practical and a suspension element 15 which is as long as possible. The suspension element 15, which may, for example, be constituted by a length of music wire, is supported at its upper end by a suspension 17 which defines a pivot point for the pendulum and permits the pendulum to swing in any vertical plane which passes through the pivot point. Various types of suspension are known and have been used for this purpose. These suspensions absorb very little energy from the system and are designed to reduce stresses in the suspension element 15 to a level below the fatigue limit of the material employed for the element. As is known, once such a pendulum is set swinging, the plane of its motion tends to remain fixed in space insofar as is possible. Accordingly, as the earth rotates, the apparent plane of pendulum motion rotates with respect to a frame of reference which is fixed relative to the earth.

While the pendulum system may be constructed so that the energy losses on each swing are quite small, ultimately the motion will be damped due to unavoidable air drag losses and the amplitude of the swinging motion will decrease. Thus, unless this energy is replaced, the system will come to rest and must then be restarted with elaborate precautions to insure that the swing is started in a plane and does not contain any minor components of motion transverse to the main direction of swing. Such transverse components would result in an elliptical movement.

The drive system according to the present invention adds kinetic energy to the pendulum bob on each swing as it passes through its rest position so that the swinging motion is sustained. The bob 13 carries an elongate cylindrical magnet 19 which is magnetized along its length and is oriented with its magnetic axis aligned with the suspension element 15. The pendulum swings over a slightly dished base 21. Base 21 preferably has indicia on its upper surface indicating the various points of the compass so that the apparent rotation of the pendulum's plane of swing relative to the earth can be noted.

A drive coil W1, wound in a pancake configuration, is mounted in base 21 directly beneath the rest position of the bob 13. A sensing coil W2, which is of larger diameter than the drive coil W1, is set into the surface of base 21 concentrically with the drive coil W1.

Set into the surface of the base 21 around its periphery are a plurality of lamps 23 for indicating the angular positions through which the plane of pendulum swing has passed during a given interval. Each of the lamps 23 is selectively energized by means of a respective latching amplifier LA which is triggered into energizing the lamp by a respective reed switch 25 which is closed when the magnet 19 passes over it. After being triggered, each latching amplifier LA keeps the respective lamp 23 lit until a manually controlled reset signal is applied. The latching amplifiers LA are preferably constituted by silicon controlled rectifiers operated on direct current. These devices have an inherent latching characteristic and, once triggered, remain conductive until the forward current flow is stopped by outside means.

When the pendulum swings so that the magnet 19 passes over the sensing coil W2, an electrical signal is developed in that winding. This relatively weak signal is amplified in a preamplifier PA and the amplified signal is applied to a Schmitt trigger circuit ST. The Schmitt trigger circuit ST operates to convert the relatively low frequency signal obtained from the sensing coil W2 to a sharp pulse. The pulse signal obtained from Schmitt trigger ST is applied to a monostable or one-shot multivibrator MW which responds by generating an output signal of predetermined duration. The multivibrator output signal, operating through a buffer amplifier BA, triggers a D.C. power supply PS. The power supply energizes coil W1 with unidirectional or direct current for the period determined by the monostable multivibrator MM.

The operation of the system is as follows. The pendulum is started in a conventional manner. As the bob 13 swings toward its rest position, the magnet 19 first crosses over the sensing winding W2 and generates a signal therein. This signal operates, as explained above, to cause the coil W1 to be energized by the D.C. power supply PS for a predetermined period determined by the characteristics of monostable multivibrator MM. The energization of coil W1 draws the magnet 19 toward the center of the coil, thereby adding kinetic energy to the pendulum bob. The period or interval of energization of coil W1 is selected, by adjustment of the multivibrator timing components, to provide energization of winding W1 only while the magnet 19 is approaching the center of the coil. The coil is deenergized as the bob 13 passes...
through its rest position. The net energy thus added to the bob replaces that lost by air drag and by hysteresis of the suspension system. It should be noted that energy is added without the use of moving parts in the drive system. As the energy losses due to air drag tend to increase substantially nonlinearly with increasing swing amplitude while the energy added by the drive system tends to remain substantially uniform, the drive system is substantially self-regulating as long as the coupling between magnet 11 and coil W1 is kept substantially constant. The drive will thus maintain a preselected swing amplitude for a given level of energization of the drive winding W1 under such conditions.

If, however, the distance between the pendulum bob 13 and the base 21 varies, e.g., due to differences in the thermal expansion of the suspension element 15 and the structure within which the pendulum is erected, the amount of kinetic energy imparted to the bob on each swing will also change and the amplitude of swing may depart appreciably from the desired level. As the bob 13 comes closer to the drive winding W1 more energy is added and the swing amplitude increases. To minimize such variations in swing amplitude, the apparatus illustrated includes a copper ring 29 larger in diameter than the windings which is set into the surface of the base 21 concentrically with the windings W1 and W2. As the magnet 17 swings by this conductive ring, eddy currents are induced in the ring after the amplitude of swing reaches a preselected level thereby damping the movement of bob 13. The amount of damping increases as the bob comes closer to the ring and thus offsets the increased drive which also results from the reduced clearance. Accordingly, a relatively stable swing amplitude is obtained in spite of variations in the clearance.

The amplitude of swing may also be regulated or limited by means which sense the field of the magnet 19 or near maximum swing of the pendulum, e.g., another winding or reed switches, and which operate to inhibit the drive system or to reduce its power output.

Since energy is added to the system by means of attraction towards the rest position, it can be seen that this drive system will maintain the pendulum swing without introducing perturbations which would introduce a component of movement transverse to the main plane of the swing and thereby produce an elliptical pattern of motion. While separate sensing and drive coils have been illustrated, a single coil may be employed to both sense and drive by providing suitable switching, isolation or buffering between the input and output circuits.

In view of the above it will be seen that the several objects of the invention are achieved and other advantageous results attained.

As various changes could be made in the above apparatus and methods without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An omnidirectional drive for a pendulum comprising:
   - a magnet which swings with said pendulum;
   - an inductor coil positioned beneath said pendulum and concentrically aligned with the pendulum in its rest position;
   - a unidirectional current supply for energizing said coil to attract said magnet toward the center of said coil;
   - means responsive to the field of said magnet for sensing the position of said magnet relative to the periphery of said coil and for providing a signal as the pendulum reaches a predetermined angular position relative to its rest position; and
   - means responsive to said signal for triggering said current supply to energize said coil for a predetermined period only as the magnet swings toward the center of the coil and to deenergize said coil before the magnet passes the center of the coil whereby kinetic energy is added to the pendulum without introducing components of motion transverse to the plane of the pendulum's swing which would produce an elliptical pattern of motion.

2. A drive as set forth in claim 1 wherein said means for sensing the position of said magnet includes a second coil which is concentric with and of a diameter at least as large as that of said inductor coil, said second coil providing said signal as said magnet swings thereby.

3. A drive as set forth in claim 2 wherein said means for triggering said power supply includes a monostable multivibrator for providing a preselected period of energization of said inductor coil.

4. A drive as set forth in claim 3 including a trigger circuit for applying to said multivibrator a sharp triggering pulse derived from the signal provided by said second coil.

5. A drive as set forth in claim 1 including means responsive to the field of said magnet for limiting the amplitude of swing of said pendulum only after said amplitude reaches a preselected level.

6. A drive as set forth in claim 5 wherein said swing regulating means includes a conductive ring larger than said coil and concentrically aligned with the pendulum in its rest position, the swinging of said magnet past said ring being operative to generate eddy currents in said ring which damp the swinging of said pendulum.

7. An omnidirectional drive for a pendulum comprising:
   - a magnet which swings with said pendulum;
   - an inductor coil positioned beneath said pendulum and concentrically aligned with the pendulum in its rest position;
   - a D.C. current supply for energizing said coil to attract said magnet toward the center of said coil;
   - a sensing coil which is concentric with and larger than said inductor coil and which is responsive to the field of said magnet for providing a signal as the pendulum reaches a predetermined angular position relative to its rest position; and
   - means including a monostable multivibrator responsive to said signal for triggering said current supply to energize said coil for a preselected period only as the magnet swings toward the center of said inductor coil, said preselected period being of a duration such that said drive coil is substantially deenergized when said pendulum reaches its rest position whereby kinetic energy is added to the pendulum without introducing components of motion transverse to the plane of the pendulum's swing which would produce an elliptical pattern of motion.

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