United States Patent

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[33] **Italy**
[31] **14870 A/69**

[54] **A GENERATOR OF HARMONIC SIGNALS WITH A HELICAL SPRING**
6 Claims, 10 Drawing Figs.

[52] **U.S. Cl.** **84/1.04,**
84/1.06, 84/1.15, 84/1.16
[51] **Int. Cl.** **G10h 3/00**
[50] **Field of Search** 84/1.16,
1.15, 1.04, 1.06 D, 1.06 E, 1.06 MR, 173, 174, 199, DIG. 21, 1.14; 310/15, 25; 333/30

[56] **References Cited**

UNITED STATES PATENTS

1,409,657	3/1922	Boynton	84/199
1,852,795	4/1932	Wegel	333/30
1,961,410	6/1934	Wegel	84/1.16
2,026,841	1/1936	Lesti	84/1.15
2,480,131	8/1949	Hammond	84/1.14
2,568,862	9/1951	Martin	84/1.16
3,297,813	1/1967	Cookerly et al.	84/1.16

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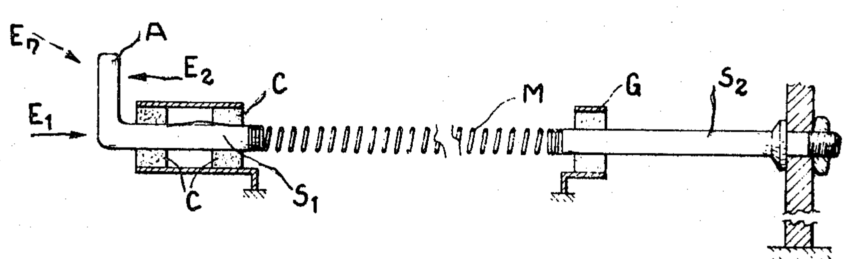
ABSTRACT: A generator of harmonic signals consisting of a spiral spring that is caused to vibrate in a longitudinal direction and means to cause said longitudinally directed vibrations thereof. Means to detect said vibrations are provided, in the form of a coil-shaped pickup which operates on the basis of magnetic changes, as provided therein by a magnetic field permanently associated with said spring.



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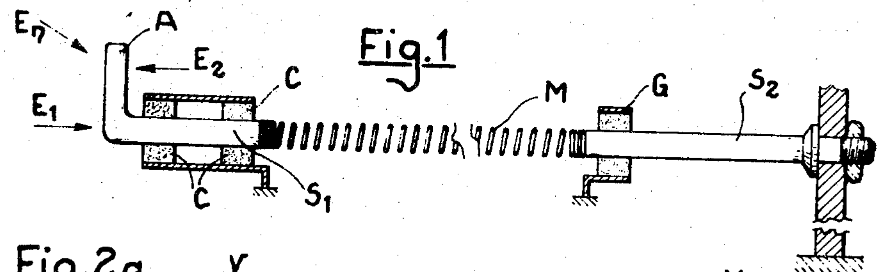

Fig.1

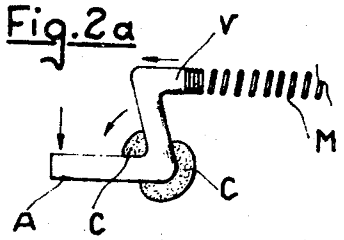

Fig.2a

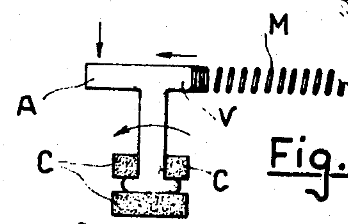

Fig.2b

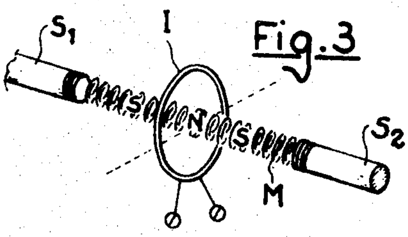

Fig.3

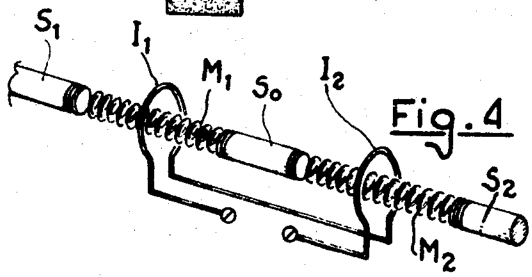

Fig.4

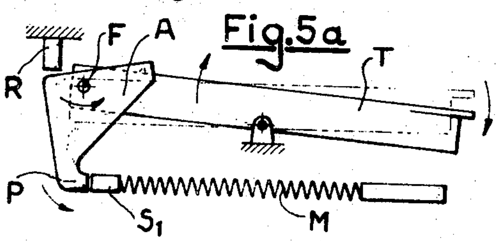

Fig.5a

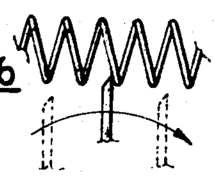
Fig.5b

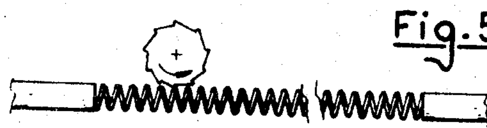
Fig.5c

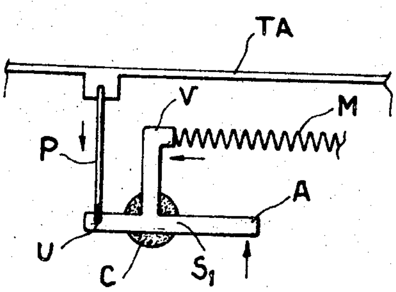

Fig.6

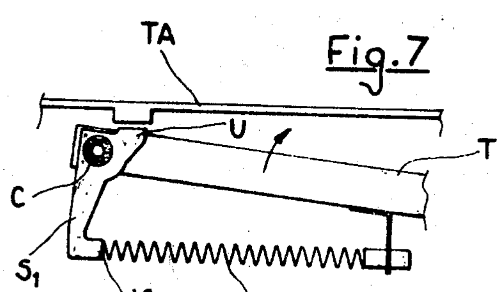

Fig.7

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GENERATOR OF HARMONIC SIGNALS WITH A HELICAL SPRING

BACKGROUND OF THE INVENTION

This invention relates to the generation of harmonic signals, e.g. musical notes in particular for musical instruments, as obtained by the vibration of metallic elements, and the picking up of such vibrations means of electronic devices.

More specifically, an object of this invention is to provide a novel generator of harmonic signals, adapted to positively prevent the hereinafter stated ill effects and drawbacks of the heretofore known signal generators which include harmonic wires or strings which are caused to vibrate in a radial direction. The generator according to the invention provides a higher purity of the produced sound, as well as a remarkable structural simplification of all musical instruments employing the same.

BRIEF SUMMARY OF THE INVENTION

Accordingly, the harmonic signal generator of this invention is characterized in that it comprises a vibrating element consisting of a helical spring to which a longitudinal vibration is imparted, such spring being supported at least at one of its ends and having preestablished dimensional features, whereby a particular fundamental frequency of longitudinal vibration corresponding to a musical note to be emitted is assigned to the same.

As already well known, vibration of a helical longitudinal or axis shows a propagation speed of an initially localized perturbation which is directly proportional to the gauge of the helically wound elastic wire and inversely proportional to the square of the spring coil average diameter.

The generator of the invention utilizes stationary harmonic oscillations that arise in a given length of a helical spring, as defined e.g. by a support at either end thereof, due to a perturbation reflection caused by the discontinuities as represented by said support. The distribution of amplitudes, speeds and accelerations on one side and of pitch changes and forces related thereto on the other side, shall obviously be sinusoidal all along the helical spring axis, thereby showing a remarkable analogy with what happens in harmonic strings.

However, it is to be remarked that in such strings, the useful motion of particles thereof is perpendicular to string axis and the force by which a string is brought back to its inoperative position depends on the applied stretch, while in a helical spring the useful motion is parallel to the axis thereof and the return force corresponds to elastic reaction of said spring.

Thus in a signal generator according to this invention, a "-fundamental" oscillation firstly occurs, having a frequency the value of which depends on the above stated two diameters (i.e. wire gauge and coil diameter), and is obviously inversely proportional to the number of active coils. Such "fundamental" shows, as usually, an antinode at its center and a node at each end support.

Along with said "fundamental," a number of harmonic oscillations occur, which contribute to deepness of tone color in the resulting total sound.

In conventional harmonic strings, the fundamental frequency is strictly dependent on the square root of the applied axial stretch. Therefore, such stretch must be kept carefully constant, in spite of thermal and dynamic stresses to which the instrument is subjected during the use thereof, in order that the tuning—i.e. the correspondence of effective frequency to nominal frequency of a note—be kept within sufficiently narrow tolerance limits.

Moreover, the value of said required tensile stretch easily attains 100 kg. (220 pounds) and more, e.g. for piano wires and from the sum of stretch of many strings the necessity results to provide very sturdy frames and supports and thus also a very heavy and expensive construction.

Conversely, as stated above, the length of the spring utilized in this invention, that will be called hereinafter "harmonic spring," has a vibrating frequency which is independent from

the force applied at both ends thereof. This force amounts to only the very small tensile stretch that is necessary to support the weight of the helical spring, in order to maintain the spring in a stable, nearly straight condition and to takeup slack resulting from assembling the instrument. Thus, both from the noninterference of said tensile stretch with the frequency and from the small value thereof, clearly ensure two of the main advantages of this invention over the conventional strings, i.e.: higher tuning stability and lightness of the whole structure.

In addition, referring to the harmonic quality of sound, which as is well known is correlated with the closeness of the obtained harmonic frequencies to exact whole multiples of the fundamental frequency, the main obstacle encountered in applying harmonic strings consists in the bending stiffness thereof, by which the theoretical conditions are disturbed due to corresponding increments in the axial tensile stretch which moreover have a different value for each harmonic frequency.

Conversely, in the "harmonic spring" of the invention the oscillatory motion is directly caused by the elastic reaction thereof, which tends to be uniform for different harmonic frequencies and their value, as stated above, does not depend on axially directed forces. Therefore very high harmonic qualities, even in the case of low notes can be attained with a harmonic spring, and above all with a spring having a small pitch and manufactured with a good uniformity, also taking into consideration its small size.

Finally, while nearly all string instruments require the strings to be directly excited, owing to the stiffness of their supports, as required by the axial stretch applied and maintained, the harmonic spring is adapted to be excited both directly and indirectly, in this latter case through one of its supports, as will be explained more detailedly later on. This allows a wide selection of the type of exciting member and the direction of motion thereof, which on the other hand with the harmonic strings must be substantially radial only, and moreover requires critical features for the exciting member.

It is to be pointed out that the helical spring according to the invention may be rigidly or nearly rigidly supported at one end, and slidingly or freely supported at the opposite end. In this latter case, as is well known, a vibration node will be formed at the fixed end and an antinode at the opposite end, which results in a halved fundamental frequency and in the presence of odd harmonics only, as well as in the generation of a corresponding sound having a peculiar tone color that would be impossible to obtain with harmonic strings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a first embodiment of a harmonic signal generator according to the invention.

FIGS. 2*a* and 2*b* are views of modified embodiments of the support means adapted to support a helical spring as shown in FIG. 1.

FIGS. 3 and 4 are views of embodiments of means to pickup the longitudinal vibrations of a helical harmonic spring according to the invention.

FIGS. 5*a* and 5*b*, and 5*c* are diagrammatic views of three devices adapted to excite longitudinal vibrations in a helical harmonic spring according to the invention.

FIGS. 6 and 7 are views of a helical harmonic springs as applied to instruments adapted to directly convert the vibratory energy into sounds by means of harmonic tables, membranes or the like.

DETAILED DESCRIPTION OF THE INVENTION

In order to detailedly described a harmonic spring along with the main generator components according to this invention, reference is made to FIG. 1 wherein a typical case of an indirectly excited spring, secured to two supports, is diagrammatically shown. The helical spring M is fastened at its ends to supports S_1 and S_2. The spring is excited e.g. through the lever arm A of the support S_1 in either optional directions E_n, preferably e.g. by a percussion in the direction E_2 or E_1. Such percussion that is transmitted to one of the spring ends through S_1 will start a spring vibration. It is now important to point out that a spring held between two rigid supports may be caused to vibrate in many simultaneous ways, e.g. in both the longitudinal and radial directions. But, while the useful signal having the highest purity and quality is generated by the longitudinal vibrations only, as previously stated, all other vibrations are to be considered spurious, and their effects should be attenuated to the highest possible degree.

Accordingly, S_1 is an intentionally semirigid support, i.e. a support which is neither rigidly connected with the stationary frame, nor wholly free. More specifically, S_1 is held by one or more pads C made of a material having a suitable compliance and is kept between said pads under a suitable radial pressure, whereby a degree of freedom of movement is allowed to said support S_1 in a direction parallel to its main axis.

The mechanical impedance opposed by S_1—owing to the combination of its compliance with its own mass—to longitudinal oscillations of the spring is sufficiently high in respect of the characteristic impedance of spring, to maintain the spring vibration for a time sufficient for musical purposes simultaneously, the tendency of the spring to vibrate like a harmonic string, i.e. in a radial direction, is greatly reduced or even suppressed, since such spurious radial vibrations result in a deviation of S_1 from the reset position of the axis thereof. In fact, the supports C are alternatively compressed and released, thus absorbing the greater part of the energy and reducing the duration of said spurious radial oscillation down to a negligible time, or even to a single transient aperiodic pulse.

Also the other support S_2 normally fastened to the opposite spring end, may be fitted with a guide or sliding block G, made of a sound-deadening material and located near the spring-support junction point, to cooperate with the opposite spring end to damp the spurious radial oscillations. Said guide G acts also as a fixed node for the longitudinal oscillations, as in said axial direction it shows a very high stiffness, without any energy-dissipating effect.

As it can be readily appreciated, the advantages ensuing from the provision of pads C, wherein the support S_1 is fitted, and also of guide G, are also attained when the harmonic spring is directly excited. However, a further important function is accomplished by the support S_1 when an indirect excitation, as shown in FIG. 1 is provided. As previously stated, a reflection efficiency markedly preferential in the direction of oscillating spring axis is shown by said support S_1. On the basis of similar considerations, it becomes apparent that, even in the course of forwarding or transmitting excitation pulses from A toward the spring, the spring axial component of said pulses is preferentially selected by said support S_1, while all other undesirable components are damped and thus not forwarded to the spring. Such effect may be exploited by providing a support S_1 formed with suitably shaped and directed extensions A adapted to receive excitation pulses from directions different from that of the spring axis, and even perpendicular thereto. In FIG. 2*a* an L-shaped support S_1 is shown, having a rotary preferential motion around a fulcrum as defined by the pad C, whereby while a percussion may be imparted vertically in the direction of the arrow, a substantially axially directed pulse is forwarded to the spring at the connection of its end with the arm V which will perform a small peripheral movement in a practically horizontally direction.

The reciprocating rotary motion as performed by the whole support makes it possible to select the most convenient transmission ratios between the support arms, such as A and V. Therefore, the mechanical impedance, intended as the ratio of force to peripheral speed with respect to a defined point may be converted from one lever arm to another having different values, since said mechanical impedance varies inversely to the square of the lever arm length. A T-shaped support S_1, as shown in FIG. 2*b* is designed for the same purposes, and a further explanation thereof can be avoided.

Therefore exciting pulses are transmitted to the spring in a direction as close as possible to the axis thereof and said spring can enhance just the longitudinally directed oscillations, while all other undesirable oscillations are damped in order to obtain an oscillating motion having a remarkable musical purity. The vibrations may be converted into an electric signal by means of a pickup, in order to enlarge the application of the harmonic springs, said electric signal being then amplified and converted into a sound by well known electronic reproducing means. Strictly speaking, the harmonic spring vibrations may be detected even by already known conventional means, e.g. piezoelectric pickup or electromagnetic detectors similar to those utilized in gramophones on which are fitted closely to a spring end owing to their relatively high mechanical impedance, as in some artificial echo devices. However, such an arrangement would provide certain drawbacks, as e.g. a change in the related spring end vibrating conditions, a traction of a not negligible oscillatory energy therefrom and a simultaneous detection of residual spurious—e.g. radial—vibrations, which similarly to what occurs in harmonic strings, would give rise to a reciprocating axial force (having a frequency double the corresponding vibration) in the node. Thus, the invention also relates to a novel detection system, by which the above-stated drawbacks are simultaneously obviated, and that will be described hereinafter with reference to FIG. 3. Referring to said FIG. 3, M is a typical harmonic spring held between two supports S_1 and S_2, as previously described. I is a stationary ring-shaped winding, consisting of one or more coils according to required electric impedance thereof, and coaxially surrounding the spring in spaced relationship therewith. The spring M, typically made of a steel wire, is permanently magnetized e.g. with a magnetic pole lying in a spring rest condition at the center of I and with the opposite poles located symmetrically on either side of I. It will be apparent that when the spring vibrates in a longitudinally direction, the center pole will be alternately shifted on either side of I, thus inducing therein an electromotive force that depends on changes in the net magnetic flow encompassed by I and that represents the required electric signal.

The above system is wholly free from the above-stated drawbacks, as e.g. from disturbances ensuing from the supports S. Moreover, no appreciable vibratory energy is absorbed and no spurious reaction of nodes is picked up. In addition, it can be readily appreciated that any residual radial spring vibration does not induce in I a corresponding detrimental voltage signal, since the related radial motion occurs in a plane parallel to that of the coil winding I and therefore will not be picked up by the same. Thus, this detection system preferentially detects longitudinal oscillations and cooperates, as it can be readily appreciated, with the mechanical structures already described with reference to FIG. 1 in order to give a resulting signal having the highest purity. Obviously, the coil winding I can be located at any point along the spring axis, thus allowing a selection of preferred tone color. Two or more coil windings I may be fitted on a single spring in order to obtain a resulting signal ensuring from suitable combinations of single voltages.

One of the different possible configurations as ensuing from the above-stated principles of the invention, is shown as an example only in FIG. 4. Two identical springs M_1 and M_2 are series connected by an intermediate support S_0 while the other supports S_1 and S_2 act as previously described. M_1 and M_2 caused to oscillate at the same frequency and in phase opposition to maintain a dynamic equilibrium, whereby S_0 is kept stationary in spite of its small mass and of the fact that it is not supported. A corresponding whole signal is picked up by two series connected windings I_1 and I_2. In a practical application, M_1 and M_2 can form a single spring having a double number of turns, wherefrom the second harmonic is picked up as a fundamental vibration signal. Obviously, the magnetic polarities of single sections M_1 and M_2 and the winding directions of I_1 and I_2 should be selected accordingly.

The generator-tuning operation, i.e. the adjustment of the spring natural vibrating frequency to a value as required from the corresponding musical note can be accomplished according to an advantageous hereinafter described system as proposed by this invention. Assuming as uniform the spring wire gauge value, the remaining two parameters, i.e. the number of active coils and the coil diameter, can be suitably changed. In fact, a first approximate tuning may be accomplished by adjusting the number of active coils in such a manner as to inversely vary the obtained frequency. This can be easily done by utilizing threaded supports S, having a diameter and a pitch adapted to thread thereon a number of spring coils which will thus be made inoperative. A fine tuning operation may be accomplished according to the invention by imparting a suitable torsion to the whole spring, through a relative rotation of the end supports at a conveniently selected angle. In such a manner the diameter of active coils and simultaneously the number of active coils are modified, said diameter and number changes having an opposite effect on the frequency variation. However, since the frequency variation is determined by the square of said coil diameter and directly influenced by the coil number, the frequency variation caused by the coil diameter change will prevail with an advantageously smooth action. Obviously, torsion may be applied in either direction, depending on whether a frequency increase or decrease is required. Further in order to maintain the torsion unchanged during the spring operation, the support S_1 (see FIG. 1) is prevented from rotating about the spring axis, e.g. by providing a prismatic rather than a cylindrical shape thereof, while the fine tuning torsion is applied by rotating the support S_2 and at the end of operation rigidly locking the same by suitable means.

A few examples of suitable excitation means for harmonic springs are shown in FIGS. *5a* and *5b* and *5c*. FIG. *5a* shows an indirect percussion system operated by a key. Pivotally connected as in F to the rear end of a key T is a lever A. When said key is acted upon, the lever A is lifted and comes into contact with a stationary stop R, whereby it is forced to rotate in a counterclockwise direction and thus strikes its end P against the support S_1 of the harmonic spring M. It is to be pointed out that the spring, as it can be readily appreciated, continues to vibrate even if after percussion, P remains in contact with S_1. The higher mechanical impedance as shown by the assembly P–S_1 may optionally give further advantageous features to the obtained sound. At any rate, the necessity of an escapement device intended to draw the striker, just after its action, away from the striken body—as is essential in the case of a direct excitation—is wholly avoided, with a remarkable simplification in the striking mechanism.

FIG. *5b* diagrammatically shows a direct plucking action as exerted on a harmonic spring by a rotating plectrum, while FIG. *5c* diagrammatically shows a direct rubbing action as exerted by a suitably roughened rotor which is kept tangent to the spring in order to longitudinally graze the same during the rotations thereof.

From the above description it is obvious that many musical instruments fitted with harmonic springs may be easily conceived by those skilled in the art, at least under the form of variants of the already known musical instruments, wherein harmonic springs according to this invention are substituted for conventional strings or reeds, said instruments being preferably of the mechanic-electronic type in consideration of the great advantages offered by the amplification thereof, both to obtain high sound volumes and to draw the greatest advantage from the above-described induction detector.

However, the invention may find also purely acoustic applications, i.e. without amplification, wherein the energy to be converted into a sound is directly drawn from the vibratory mechanical energy of the spring by means of harmonic tables, membranes or the like. This is particularly suitable wherein an exiguous sound volume and poorer sound quality are acceptable. An example is diagrammatically shown in FIG. 6. The support S_1, its resilient bearing pad C and the lever arms A and V are wholly similar to the components as described above with reference to FIG. *2a*. A third lever arm U is provided to transmit the torsional vibrations imparted to the spring M by the entire support S_1 to a harmonic table TA, through a rod P. Finally, a simpler acoustic embodiment is diagrammatically shown in FIG. 7. The support S_1 is borne by the same key T through a resilient fulcrum pad C, and its lever arm V is connected with the spring M. The other lever arm U of the support S_1 is designed to perform the same operation assigned to lever arm A in FIG. 6. In fact, as soon as the key T is depressed, the lever arm U directly strikes the harmonic table TA, thereby causing firstly a vibration of spring M and successively, when contact is maintained the spring vibrations are directly transmitted to TA by the lever arm U. When the key is released, the sound is automatically discontinued, since the lever arm U is longer in contact with TA, even if the spring M continues to vibrate.

According to the selected excitation system (percussion, plicking, rubbing, etc.) as well as to the excitating means (a key, the hand, etc.), it is possible to obtain pianos, clavicembalos, vibraphones, cithers, etc.

The harmonic springs may comprise a damping member, wholly similar to already known dampers and obviously designed to tonedown the sound, as soon as it is no longer desired.

Finally, to fit side by side a plurality of harmonic springs, in order to form a multinote instrument such as those already used, the solution of only a few and otherwise common problems, relating to size limitations, e.g. longitudinally to the keyboard, as imposed by a prefixed pitch between the notes, is required.

While the invention has been described in detail in terms of preferred examples and embodiments thereof, it will be understood that various changes and modifications may be made therein by those skilled in the art, without departing from the spirit and scope of the invention, as defined in the following claims.

I claim:

1. A harmonic signal generator comprising a helical spring; support means connected to each end of said spring; semirigid mount means for mounting at least one of said support means to impart a degree of freedom of movement thereto and to said spring in the longitudinal direction thereof; but preventing movement in the radial direction thereof; means for imparting longitudinal vibrations to said spring; said spring being magnetized to have a magnetic pole spaced from said support means; and electromagnetic pickup means including a stationary coil coaxially surrounding said spring in spaced relation thereto, such that the plane of said coil is perpendicular to the longintudinal axis of said spring, and said magnetic pole is in said plane when said spring is not vibrated, whereby longitudinal movement of said pole out of said plane due to said vibrations generates an electromotive force in said coil.

2. A device as claimed in claim 1, wherein said means for imparting longitudinal vibrations includes means for causing a percussion to said semirigid mount means.

3. A device as claimed in claim 1, wherein said means for imparting longitudinal vibrations includes means acting directly on said spring.

4. A device as claimed in claim 1, wherein said semirigid mount means comprises a bracket surrounding at least one of said support means with yieldable material positioned therebetween, said yieldable material providing means to dampen said radial movement.

5. A device as claimed in claim 1, wherein at least one of said support means includes means to change the number of operative coils of said helical spring.

6. A device as claimed in claim 1, further comprising means operatively associated with at least one of said support means to impart axial torsion to said helical spring to cause slight changes in the coil diameter thereof.

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