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PROVISIONAL SPECIFICATION

Improvements in or relating to Spring Assemblages

I, EDMUND RAMSAY WIGAN, of "Riccarton", 35, Montague Road, Southbourne, Hampshire, a British Subject, do hereby declare the nature of this invention to be as follows:—

This invention relates to mountings for flexible mechanical assemblies and it has for its object an improved adjustable mounting of this kind, of the type in which a resilient flexible member is clamped at or near both ends on either side of a point or portion of the said member, the motion of which it is desired to control.

According to my invention, I provide a mounting for flexible mechanical assemblies, of the type described, comprising a resilient flexible member or members clamped at or near both ends or rigidly but adjustably secured to rigid supports so spaced and orientated that the flexible assembly has applied to it simultaneously a compressive force and bending moments of desired magnitudes and distribution, and means for varying the stiffness of the said member or members.

The said means may consist either in an adjustment of the relative inclination of the ends of the said member or members by the rotation of one or of the two supports about a suitable axis or axes, or in an adjustment of the ratio of the length of the said flexible member lying between the said supports to the space between the said supports by altering the length of the said member or members while keeping the space between the supports constant, or by altering the space between the supports while keeping the length of the flexible member a constant quantity, or by altering both the length of the said member or members and the space between the supports; rotation of a support or of both supports together with adjustment of the said ratio may also be employed.

When a resilient flexible member is clamped in the manner described, so that its length measured between the points of support is greater than the straight line joining the two points of support, the latter exert on the said member a compressive force which causes it to assume a curvilinear shape; at the same time, in all cases in which the curvilinear shape is unsymmetrical, a couple is brought into existence at each support by the reaction of the clamping means upon the resilient flexible member. The lateral stiffness of the flexible member measured in the plane in which the curved axis of the member lies when in such a condition of strain depends on the above-mentioned forces, and bending moments or couples, which themselves depend on the relative inclination of the ends of the flexible member and also on the value of the ratio mentioned above.

The axes of the two supports may be parallel or they may be inclined to each other and either in the same plane or in parallel planes or in planes inclined to each other. For the sake of simplicity, we shall only take into consideration the case in which the two axes are parallel and the axis of the resilient flexible member is in a plane perpendicular to the axes.

Referring to the drawings left herewith, which illustrate the principle which is the basis of a mounting for flexible mechanical assemblies according to my invention:—

Fig. 1 is a diagrammatic plan of a mounting according to my invention;

Figs. 2b, 2c, 2d, 2e, 2f are diagrams representing some of the curved forms that may be assumed by the resilient flexible member when mounted in the manner described. Each successive figure illustrates a system of less positive stiffness.

Fig. 2a shows the member in an initial state prior to the adjustment of bending moments and compressive forces.

Fig. 3 is a diagrammatic elevation or plan of a parallel motion mounting in one of the configurations according to my invention.

In Fig. 1, 1 is the resilient flexible linear member, which, for the sake of illustration, is assumed to be a long flat strip of spring steel, straight when in an unstrained condition, clamped to two supports 2, 2′ near the ends of the strip, by means of screws 3, 3′, so that any line in the strip perpendicular to its axis is vertical.

The supports 2, 2′ are mounted on a base plate 4 on which they are capable of rotating about axes perpendicular to the plane of the paper and they are adapted to be secured in any desired angular position by means of set screws 5, 5′. The axis of the member 1 has in general three points of inflexion, one near each support and one near the centre 6. When a force is applied laterally to the member 1 at any point thereof, the central point 6 moves along a line *xy*, referred to hereafter as the "preferred" or "permitted" line of motion of the point 6. In the Fig. 1, the supports are adjusted so that the clamped ends of the strip are exactly parallel, the shape assumed by the strip if of homogeneous material, section and temper will be perfectly symmetrical, as shown. The preferred or permitted line of motion of 6 is, for small excursions, perpendicular to the centre line of the supports 2, 2′, the amplitude of linear motion that is possible depending on the value of the ratio *r* of the length *l* of the strip measured between the points of support to the distance *d* between the supports.

The nature of the curvilinear shape assumed by the resilient flexible member depends also on the relative inclination of the two clamped ends of the strip and on the value of the ratio *r*. Fig. 2*a* shows the shape assumed by the strip when both supports are free to rotate about their axes.

Fig. 2*b* shows the shape when the support 2′ is rotated clockwise and then clamped. Support 2 is clamped in the position shown in Fig. 2*a*. The configuration shown in Fig. 2*b* is very stiff to forces applied as at F but being asymmetrical is of little value.

Fig. 2*c* shows the shape assumed when the support 2′ is rotated further clockwise and clamped while 2 remains clamped. This configuration is less stiff than 2*b* and being symmetrical shows a displacement of the centre 6 due to a force F which is at right angles to the line of centres.

Fig. 2*d* shows the shape when each support 2 and 2′ is rotated counter clockwise from the position of 2*c* and then clamped. The stiffness of the system to a force F grows less and less positive and passes through zero as the rotation of the supports is increased. If rotation of 2 and 2′ is carried further still configurations 2*e* and 2*f* are obtained. These are stable in the forms P1 and P3 and in unstable equilibrium in form P2. In the latter form the system exhibits negative stiffness. The shapes shown in Figs. 2*c*, 2*d* and at P2 in 2*e* and 2*f* are symmetrical: the ends of the resilient flexible member are equally oppositely inclined to the centre line of the supports. If they are not equally inclined, unsymmetrical configurations are obtained, which are less valuable from the point of view of possible mechanical applications. Perfect alignment is however not essential to the effective use of the invention.

These configurations, which arise whenever the ratio

$$r\ (=\frac{l}{d}) > 1,$$

are due to the forces exerted by the supports on the flexible member.

These forces are primarily the compressive forces, *f*, *f′* (Fig. 1). The couples *c*, *c′*, exerted by each support, respectively are zero if the undeflected conformation of the member is symmetrical as in Fig. 1, but assume finite values when the system is deflected by a lateral force, or when the undeflected conformation is asymmetrical. In the symmetrical case the bending moment responsible for the left hand loop is exactly balanced by the bending moment responsible for the right hand loop and the nett couple at the supports is zero. Careful adjustment of the angular position of the supports is necessary to obtain a symmetrical configuration for any given value of the ratio *r* (or compressive forces *f*, *f′*).

These adjustments affect at the same time the stiffness of the resilient flexible member, whether they are effected separately or simultaneously. For example, in the case of the simple system shown in Fig. 1, the flexible member affecting a "S" configuration may be given a more positive stiffness by drawing the two supports away from each other, or a less positive stiffness by moving them towards each other. In certain circumstances, by carefully adjusting the relative angular inclination of the ends of each support and the compressive force exerted by them on the flexible member, so that they have the correct magnitudes, the lateral stiffness of the central portion of the flexible member may be brought substantially to zero, that is to say, the flexible member offers no resistance to motion of the point 6 under the action of a lateral force F, and remains in any position in which it is brought (within certain limits), behaving therefore as a non-resilient flexible member. The member may then be given a negative stiffness, that is, it needs a restraining force opposed to the deflecting force F to prevent it from moving in the direction in which the said deflecting force is applied, this condition being obtained either by increasing the compressing force exerted by the supports on the flexible member, or by increasing the angle of rotation of each support, by equal amounts, as in Figs. 2*e* and 2*f*, or by increasing both compressive forces and the angles of rotation simultaneously.

The invention provides therefore a means for adjusting the stiffness of the mounting, either by varying the angle of rotation of the supports, or by varying the length *l* of the flexible member externally of the supports or by varying the space *d* between the supports. By combining these several means of adjustment, any desired nature and degree of flexibility, consistent with the dimensions, proportions and material of the members constituting the mounting, may be obtained.

In any configuration, the stiffness coefficient is not constant but tends to become more positive as the point 6 is displaced in either direction from the position of symmetry; for small displacements, however, the stiffness coefficient is sufficiently constant to enable the device to be used in applications where this is of importance. On the other hand, the stiffness coefficient varies very rapidly when the system is brought into a position which is far away from the position of symmetry, and this feature is advantageous in certain cases. For a limited amplitude of the motion of the point 6, the stiffness coefficient is sensibly constant and the displacement varies proportionally to the deflecting force. This amplitude, for which the stiffness is sensibly constant, is the greater as the angle θ is made greater by increasing the ratio r either by increasing the length l or by shortening the space d between the supports. The torsional rigidity of the flexible member in the plane of the axes of the supports is substantially unaffected by adjustment of the forces f, f′ or of the couples c, c′, as also is the rigidity to forces at right angles to the plane of the paper.

Referring to the simple embodiment shown in Fig. 1, it will be found that the point 6 will move over a relatively large distance at the result of a small deflection produced by an external lateral force applied at a point of the member remote from the centre point 6, the force required to produce a given deflection at the centre becoming smaller and smaller as the stiffness approaches zero.

It will be seen therefore that a member mounted and adjusted, in accordance with this invention, to substantially zero stiffness behaves practically as a "floating" member moving on practically frictionless bearings or guides and in an exactly defined path (this being equivalent to the bearings or guides having no "play" or "clearance"). My invention therefore may be applied to any mechanism where these properties are required. Under such conditions, the central portion of the member 1 is found to behave like a relatively stiff bar moving laterally with very little friction and, for small displacements, under no restraint other than that due to inertia.

Obviously, such an arrangement provides an ideal armature for a magnetically operated relay. The "bias" of the relay may be adjusted (e.g. by rotating either or both supports) to be "neutral" or "side-biased", the degree of side-bias becoming greater as the stiffness becomes more negative. Alternatively, the same range of adjustments may be obtained by increasing or decreasing the compressive force exerted by the supports on the resilient flexible member by varying either the length l or the distance d.

Among other applications of my invention may be mentioned a parallel motion mechanism. In certain parallel motion mechanisms in use hitherto, the moving table, object-carrier, carriage or the like is mounted on the supporting framework of the mechanism by means of flat spring-like members, thereby obtaining the desired parallel motion. In such arrangements, however, the force required to move the said table, object-carrier, carriage or the like against the stiffness of the supporting members becomes considerable if large displacements are required, whereas with a mounting construction in accordance with this invention, these forces are small.

Fig. 3 shows an embodiment of the principle of the invention to a simple parallel motion mechanism: 7 is the carriage to be displaced in the direction xx by the lead screw 8: the carriage 7 is supported by flat spring members 9, 9′ seen edgewise, each pair of opposite springs 9 and 9′ constituting one resilient flexible member such as the member 1 of Fig. 1, the ends of each of the partial members 9 and 9′ being held in slots in the carriage 7 and in the framework 10. It will be seen that the direction of bending of one pair 9, 9′ is reversed with respect to the other pair, so as to increase the range of motion of the carriage 7 within which the direction of traverse is exactly along the line xx.

A further field of application is to mechanical systems which make use of a member the stiffness of which may be varied at will. For example, the resilient flexible member may be given a negative stiffness, the value of which may be adjusted, say, by rotating the supports on their axes. A member so adjusted, after calibration, may be used to measure the stiffness of another spring, the negative (known) and positive (unknown) stiffness·s being coupled together mechanically; the stiffness of the compound system thus produced may then be reduced to zero or to any other desired value, positive or negative, by adjusting the negative (known) stiffness. If desired, the measurement may be made by bringing the compound system to resonance under the influence of a known added mass and a known driving frequency.

The region of adjustable positive stiffness may be employed in vehicle springs and the like, or in shock absorbers, where it may be desirable to vary the stiffness of the spring member in accordance with variations of load, torque, oil viscosity and other conditions affecting the performance of the device. In certain cases, the magnitude of the effect arising out of these conditions may be employed, directly or indirectly, to vary the stiffness of the resilient flexible member.

It has been explained above that the stiffness of a resilient flexible member mounted according to this invention may be varied by varying the compressive force exerted by the supports on the said member, by varying the magnitude of the couple exerted by each support on the said member or by using both these means. These changes in the forces to which the resilient flexible member is subjected do not necessarily originate outside the system, as in the examples previously described, but, if desired, they can originate in the flexible member itself. For example, the flexible member may be of bimetallic construction, designed to vary its stiffness, with a change of temperature of the said member. In a particular embodiment of this arrangement, the change of temperature may cause the member to move either in a stable or in a suddenly unstable configuration in passing from one position to another, thereby constituting a "snap" mechanism. This movement may be used to indicate the temperature of the member or to operate the closure or the break of an electric circuit for this or any other purpose.

It will be appreciated that embodiments of the invention are not limited to systems which make use of a flat spring member clamped in the manner described in the examples mentioned above, but that the invention covers any construction which embodies the characteristic principle of the combination of a compressive force exerted by the supports upon the resilient member together with bending moments, both being chosen and distributed in such a way as to confer on the said member the desired stiffness characteristic.

Dated this 9th day of November, 1945.

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COMPLETE SPECIFICATION

Improvements in or relating to Spring Assemblages

I, Edmund Ramsay Wigan, a British Subject, of "Riccarton", 35 Montague Road, Southbourne, Hampshire, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to spring assemblages and has for an object to provide means whereby the relationship between the load and deflection of the spring system may be made to vary.

According to this invention a spring assemblage comprises a spring member resilient in a direction transverse to its length, two anchorages spaced apart and carrying said spring and rotatably adjustable about parallel axes, means for fixing the anchorages in their adjusted angular positions, at least one of which anchorages is arranged to permit adjustment of the spring transversely to the axis of rotation of the anchorage and means for clamping the spring in the latter adjusted position.

The length of the spring between the anchorages and the angular position of the anchorages may be so adjusted that bends are imparted to the ends of the spring adjacent the anchorages, which bends differ in angular extent and/or which bends are arranged to be on opposite sides of a line joining the anchorages.

In either of the arrangements referred to above the spring may comprise a spring blade.

The anchorages may be arranged to apply couples and compressive forces to the ends of the spring of such value that the stiffness of the spring with respect to a force applied to the spring in a direction transverse to a line joining the anchorages in zero over a range of deflection.

The spring assemblage may comprise a rigid support together with a movable element secured intermediate of the ends of a spring-like member or members which is or are resilient in a direction transverse to its or their length, the said member or members being clamped at opposite ends by two anchorages on the rigid support in the manner set out above so that when no forces external to the assemblage are applied to the movable element, the longitudinal axis of the spring-like member or of each spring-like member crosses at least once a straight line drawn between the said two anchorages on the rigid support with or without means for modifying the shape of the path taken by the said axis by varying either the compressive or the twisting forces exerted by the said anchorages upon the said spring-like member.

Separate springs may be arranged on opposite sides of said element so as to be in alignment with one another.

The element may be supported by two

pairs of springs between two pairs of anchorages on the rigid support which springs are so strained by the anchorages on said element and rigid support that each spring on one side of the element is oppositely curved to its counterpart on the other side of the element.

Other features of the invention are set out in the accompanying description and claims.

Reference is made in the description to the drawings accompanying the provisional specification which show Figures 1 to 3, and also to the drawings accompanying the complete specification, which show in Figures 4, 5 and 6 modifications of the arrangement shown in Figure 3.

Figure 1 shows means for adjustably clamping the spring blade 1 in the anchorages 2 and 2′ and means for adjustably mounting the anchorages on the base 4.

The other figures are of a diagrammatic character in which the adjustable clamping and mounting are not shown.

In Figure 1, 1 is the resilient flexible linear member which, for the sake of illustration, is assumed to be a long flat strip of spring steel, straight when in an unstrained condition, clamped to two supports 2, 2′ near the ends of the strip by means of screws 3, 3′, so that all lines lying in the plane of the strip perpendicular to its axis, are parallel, i.e. the strip is not twisted about its longitudinal axis.

The supports 2, 2′ are mounted on a base plate 4 on which they are capable of rotating about axes perpendicular to the plane of the paper and they are adapted to be secured in any desired angular position by means of set screws 5, 5′. The axis of the member 1 has in general three points of inflection, one near each support and one near the centre 6. When a force is applied laterally to the member 1 at any point thereof, the central point 6 moves along a line *xy*, referred to hereafter as the "preferred" or "permitted" line of motion of the point 6. In the F.gure 1, the supports are adjusted so that the clamped ends of the strip are exactly parallel, the shape assumed by the strip if of homogeneous material, section and temper will be perfectly symmetrical, as shown. The preferred or permitted line of motion of 6 is, for small excursions, perpendicular to the centre line of the supports 2, 2′, the amplitude of linear motion that is possible depending on the value of the ratio r of the length l of the strip measured between the points of support to the distance d between the supports.

The nature of the curvilinear shape assumed by the resilient flexible member depends also on the relative inclination of the two clamped ends of the strip and on the value of the ratio r. Figure 2a shows the shape assumed by the strip when both supports are free to rotate about their axes.

Figure 2b shows the shape when the support 2′ is rotated clockwise and then clamped. Support 2 is clamped in the position shown in Figure 2a. The configuration shown in Figure 2b is very stiff to forces applied as at F but being asymmetrical is of little value.

Figure 2c shows the shape assumed when the support 2′ is rotated further clockwise and clamped while 2 remains clamped. This configuration is less stiff than 2b and being symmetrical shows a displacement of the centre 6 due to a force F which is at right angles to the line of centres.

Figure 2d shows the shape when each support 2 and 2′ is rotated counter clockwise from the position of 2c and then clamped. The stiffness of the system to a force F grows less and less positive and passes through zero as the rotation of the supports is increased. If rotation of 2 and 2′ is carried further still, configurations 2e and 2f are obtained. These are stable in the forms P1 and P3 and in unstable equilibrium in form P2. In the latter form the system exhibits negative stiffness. The shapes shown in Figures 2c, 2d, and at P2 in 2e and 2f are symmetrical: the ends of the resilient flexible member are equally oppositely inclined to the centre line of the supports. If they are not equally inclined, unsymmetrical configurations are obtained, which are less valuable from the point of view of possible mechanical applications. Perfect alignment is however not essential to the effective use of the invention.

These configurations, which arise whenever the ratio

$$r\ (=\frac{l}{d}) > 1,$$

are due to the forces exerted by the supports on the flexible member.

These forces are primarily the compressive forces f, f' (Figure 1). The couples c, c', exerted by each support, respectively are zero if the undeflected conformation of the member is symmetrical as in Figure 1, but assume finite values when the system is deflected by a lateral force, or when the undeflected conformation is asymmetrical. In the symmetrical case the bending moment responsible for the left hand loop is exactly balanced by the bending moment responsible for the right hand loop and the nett couple at the supports is zero. Careful adjustment of the angular position of the supports is necessary to obtain a symmetrical configuration for any given value of the ratio r (or compressive forces f, f').

These adjustments affect at the same time the stiffness of the resilient flexible member, whether they are effected separately or simultaneously. For example, in the case of the simple system shown in Figure 1, the flexible member affecting a "S" configuration may be given a more positive stiffness by drawing the two supports away from each other, or a less positive stiffness by moving them towards each other. In certain circumstances, by carefully adjusting the relative angular inclination of the ends of each support and the compressive force exerted by them on the flexible member, so that they have the correct magnitudes, the lateral stiffness of the central portion of the flexible member may be brought substantially to zero, that is to say, the flexible member offers no resistance to motion of the point 6 under the action of a lateral force F, and remains in any position in which it is brought (within certain limits), behaving therefore as a non-resilient flexible member. The member may then be given a negative stiffness, that is, it needs a restraining force opposed to the deflecting force F to prevent it from moving in the direction in which the said deflecting force is applied, this condition being obtained either by increasing the compressive force exerted by the supports on the flexible member, or by increasing the angle of rotation of each support, by equal amounts, as in Figures 2a and 2f, or by increasing both compressive forces and the angles of rotation simultaneously.

The invention provides therefore a means for adjusting the stiffness of the mounting, either by varying the angle of rotation of the supports, or by varying the length l of the flexible member externally of the supports or by varying the space d between the supports. By combining these several means of adjustment, any desired nature and degree of flexibility, consistent with the dimensions, proportions and material of the members constituting the mounting, may be obtained.

In any configuration, the stiffness coefficient is not constant but tends to become more positive as the point 6 is displaced in either direction from the position of symmetry; for small displacements, however, the stiffness coefficient is sufficiently constant to enable the device to be used in applications where this is of importance. On the other hand, the stiffness coefficient varies very rapidly when the system is brought into a position which is far away from the position of symmetry, and this feature is advantageous in certain cases. For a limited amplitude of the motion of the point 6, the stiffness coefficient is sensibly constant and the displacement varies proportionally to the deflecting force. This amplitude for which the stiffness is sensibly constant is the greater as the angle θ is made greater by increasing the ratio r either by increasing the length l or by shortening the space d between the supports. The torsional rigidity of the flexible member in the plane of the axes of the supports is substantially unaffected by adjustment of the forces f, f' or of the couples c, c', as also is the rigidity to forces at right angles to the plane of the paper.

Referring to the simple embodiment shown in Figure 1, it will be found that the point 6 will move over a relatively large distance at the result of a small deflection produced by an external lateral force applied at a point of the member remote from the centre point 6, the force required to produce a given deflection at the centre becoming smaller and smaller as the stiffness approaches zero.

It will be seen therefore that a member mounted and adjusted, in accordance with this invention, to substantially zero stiffness behaves practically as a "floating" member moving on practically frictionless bearings or guides and in an exactly defined path (this being equivalent to the bearings or guides having no "play" or "clearance"). The present invention therefore may be applied to any mechanism where these properties are required. Under such conditions, the central portion of the member 1 is found to behave like a relatively stiff bar moving laterally with very little friction and, for small displacements, under no restraint other than that due to inertia.

Obviously, such an arrangement provides an ideal armature for a magnetically operated relay. The "bias" of the relay may be adjusted (e.g. by rotating either or both supports) to be "neutral" or "side-biased", the degree of side-bias becoming greater as the stiffness becomes more negative. Alternatively, the same range of adjustments may be obtained by increasing or decreasing the compressive force exerted by the supports on the resilient flexible member by varying either the length l or the distance d.

Among other applications of this invention may be mentioned a parallel motion mechanism. In certain parallel motion mechanisms in use hitherto, the moving table, object-carrier, carriage or the like is mounted on the supporting framework of the mechanism by means of flat spring-like members, thereby obtaining the desired parallel motion. In such arrangements, however, the force required to move the said table, object-carrier, carriage or the like against the stiffness of the supporting members becomes considerable if large displacements are required, whereas with a mounting construction in accordance with this invention, these forces are small.

Figure 3 shows diagrammatically an embodiment of the principle of the invention to a simple parallel motion mechanism: 7 is the carriage to be displaced in the direction xx by the lead screw 8: the carriage 7 is supported by flat spring members 9, 9′ seen edgewise, each pair of opposite springs 9 and 9′ constituting one resilient flexible member such as the member 1 of Figure 1, the ends of each of the partial members 9 and 9′ for simplicity are shown being held in slots in the carriage 7 and in the framework 10, but in practice would be adjustable in anchorages rotatably adjustable in a similar manner to the supports 2, 2′ of Figure 1. It will be seen that the direction of bending of one pair 9, 9′ is reversed with respect to the other pair, so as to increase the range of motion of the carriage 7 within which the direction of traverse is exactly along the line xx.

The arrangement shown in Figure 4 is similar to that of Figure 3 with the exception that instead of each of the partial members 9 and 9′ being so strained as to assume an "S" shape, they assume a bow shape, and the members 9 on one side of the carriage are arranged to have their convex portions directed towards one another while the members 9′ on the other side of the carriage have their convex portions directed away from one another. Thus, in effect, the left hand partial member 9 together with the left hand partial member 9′ constitute a sine shape as do also the right hand partial members 9 and 9′.

In the arrangement shown in Figure 5, a single pair of partial members 9 and 9′ are provided and have their adjacent ends anchored to opposite flat sides of the carriage 7, the length of the portions 9 and 9′ and the distance between the sides of the carriage and the attachments to the members 10 being so selected that the spring system as a whole adopts an "S" shape.

In the alternative arrangement shown in Figure 6, a looped spring is anchored on either side of the carriage 7 between it and the members 10, which loops in their unstrained form may be circular. In this arrangement, the right hand end of the top loop 11 together with the left hand end of the bottom loop provide between them an "S" shaped spring system, as do the other two parts of the two loops.

A further field of application is to mechanical systems which make use of a member the stiffness of which may be varied at will. For example, the resilient flexible member may be given a negative stiffness, the value of which may be adjusted, say, by rotating the supports on their axes. A member so adjusted, after calibration, may be used to measure the stiffness of another spring, the negative (known) and positive (unknown) stiffness s being coupled together mechanically; the stiffness of the compound system thus produced may then be reduced to zero or to any other desired value, positive or negative, by adjusting the negative (known) stiffness. If desired, the measurement may be made by bringing the compound system to resonance under the influence of a known added mass and a known driving frequency.

The region of adjustable positive stiffness may be employed in vehicle springs and the like, or in shock absorbers, where it may be desirable to vary the stiffness of the spring member in accordance with variations of load, torque, oil viscosity and other conditions affecting the performance of the device.

It has been explained above that the stiffness of a resilient flexible member mounted according to this invention may be varied by varying the compressive force exerted by the supports on the said member, by varying the magnitude of the couple exerted by each support on the said member or by using both these means. These changes in the forces to which the resilient flexible member is subjected do not necessarily originate outside the system, as in the examples previously described but, if desired, they can originate in the flexible member itself. For example, the flexible member may be of bimetallic construction, designed to vary its stiffness, with a change of temperature of the said member. In a particular embodiment of this arrangement, the change of temperature may cause the member to move either in a stable or in a suddenly unstable configuration in passing from one position to another, thereby constituting a "snap" mechanism. This movement may be used to indicate the temperature of the member or to operate the closure or the break of an electrical circuit for this or any other purpose.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A spring assemblage comprising a spring member resilient in a direction transverse to its length, two anchorages spaced apart and carrying said spring and rotatably adjustable about parallel axes, means for fixing the anchorages in their adjusted angular positions, at least one of which anchorages is arranged to permit adjustment of the spring transversely to the axis of rotation of the anchorage and means for clamping the spring in the latter adjusted position.

2. A spring assemblage according to claim 1, wherein the length of the spring between the anchorages and the angular position of the anchorages are so adjusted that bends are imparted to the ends of the springs adjacent the anchorages which bends differ in angular extent and/or which bends are arranged to be on opposite sides of a line joining the anchorages.

3. A spring assemblage according to either of the preceding claims, wherein said spring member comprises a spring blade.

4. A spring assemblage according to any of the preceding claims, wherein said anchorages are arranged to apply couples and compressive forces to the ends of the spring

of such values that the stiffness of the spring with respect to a force applied to the spring in a direction transverse to a line joining the anchorages is zero over a range of deflections.

5. A spring assemblage comprising a rigid carrier together with a movable element secured intermediate of the ends of a spring-like member or members which is or are resilient in a direction transverse to its or their length, the said member or members being clamped at opposite ends by two anchorages on the rigid support in the manner set out in any of the preceding claims so that when no forces external to the assemblage are applied to the movable element, the longitudinal axis of the spring-like member or of each spring-like member crosses at least once a straight line drawn between the said two anchorages on the rigid support with or without means for modifying the shape of the path taken by the said axis by varying either the compressive or the twisting forces exerted by the said anchorages upon the said spring-like member.

6. A spring assemblage according to claim 5, wherein separate springs are arranged on opposite sides of said element so as to be in alignment with one another.

7. A spring assemblage according to claim 6, wherein said element is supported by two pairs of springs between two pairs of anchorages on the rigid support which springs are so strained by the anchorages on said element and rigid member that each spring on one side of the element is oppositely curved to its counterpart on the other side of the element.

8. A spring assemblage according to claim 7, wherein each said spring is so constrained by its anchorages as to follow a curve having no point of inflexion.

9. A spring assemblage according to claim 7, wherein each said spring is so constrained by its anchorages as to follow a curve having points of inflexion such as an S-shaped curve.

10. A spring assemblage according to any of the preceding claims, wherein said springs and anchorages are so arranged that they constrain said element to move rectilinearly.

11. A spring assemblage substantially as described.

12. A spring assemblage substantially as described with reference to the accompanying drawings.

Dated this 6th day of January, 1947.

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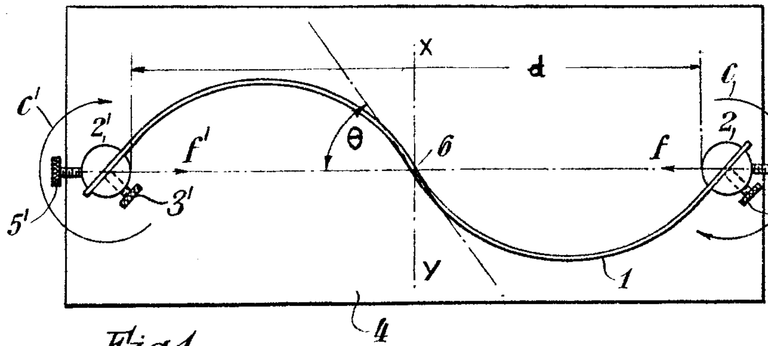

Fig.1.

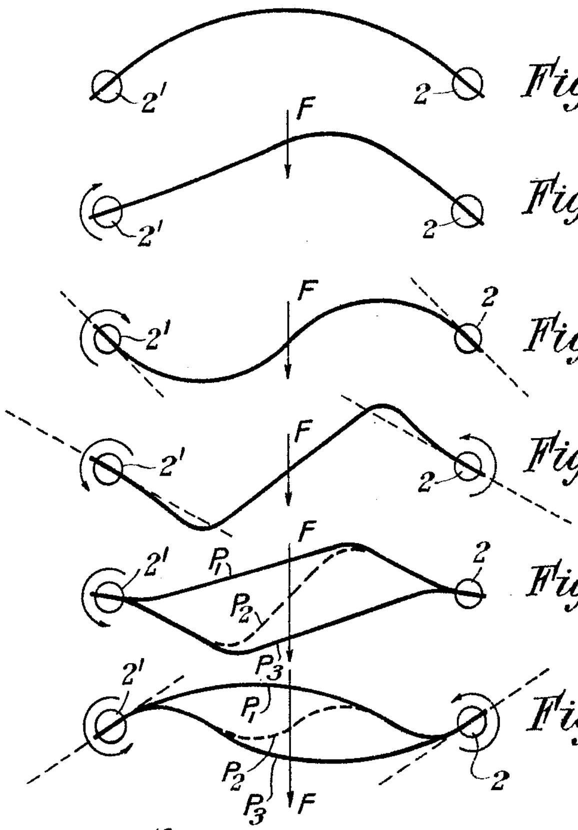

Fig.2a. Fig.2b. Fig.2c. Fig.2d. Fig.2e. Fig.2f.

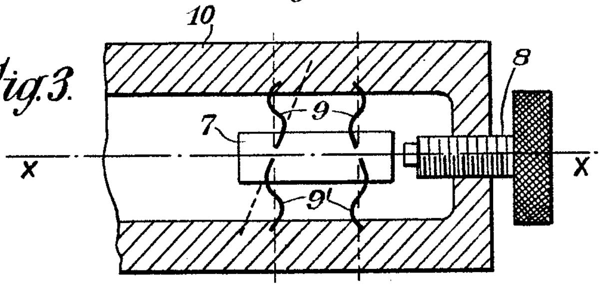

Fig.3.

[This Drawing is a reproduction of the Original on a reduced scale.]

Fig. 4.

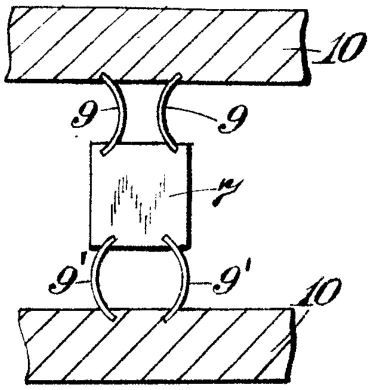

Fig. 5.

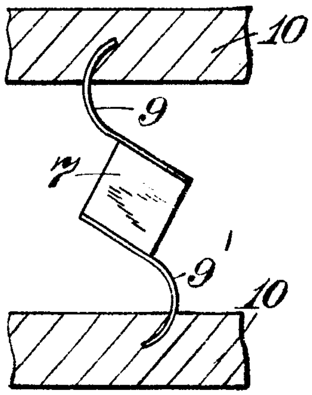

Fig. 6.