April 16, 1946. G. A. RUBISSOW 2,398,722

SELF-TUNING POLYHARMONIC DAMPER

Filed March 8, 1941 3 Sheets-Sheet 1

Fig. 1

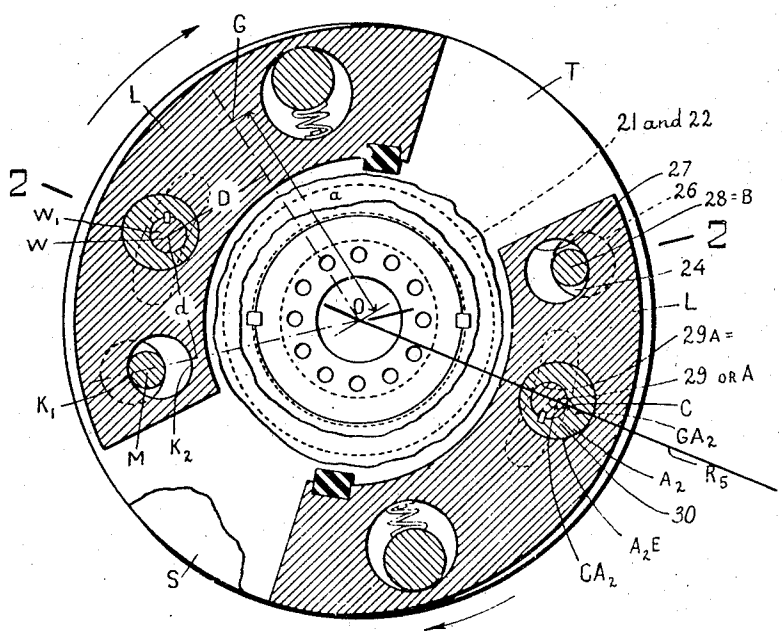
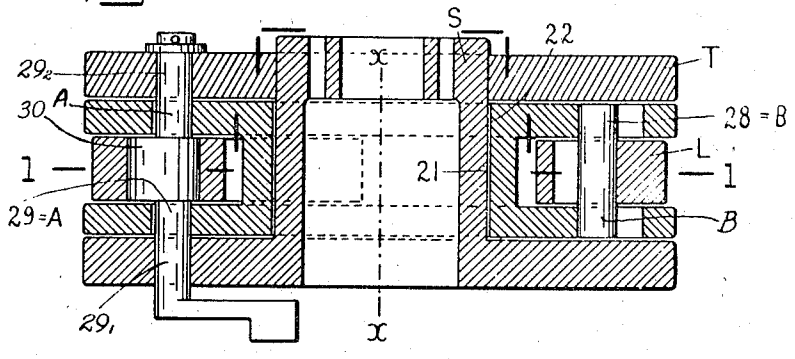


Fig. 2



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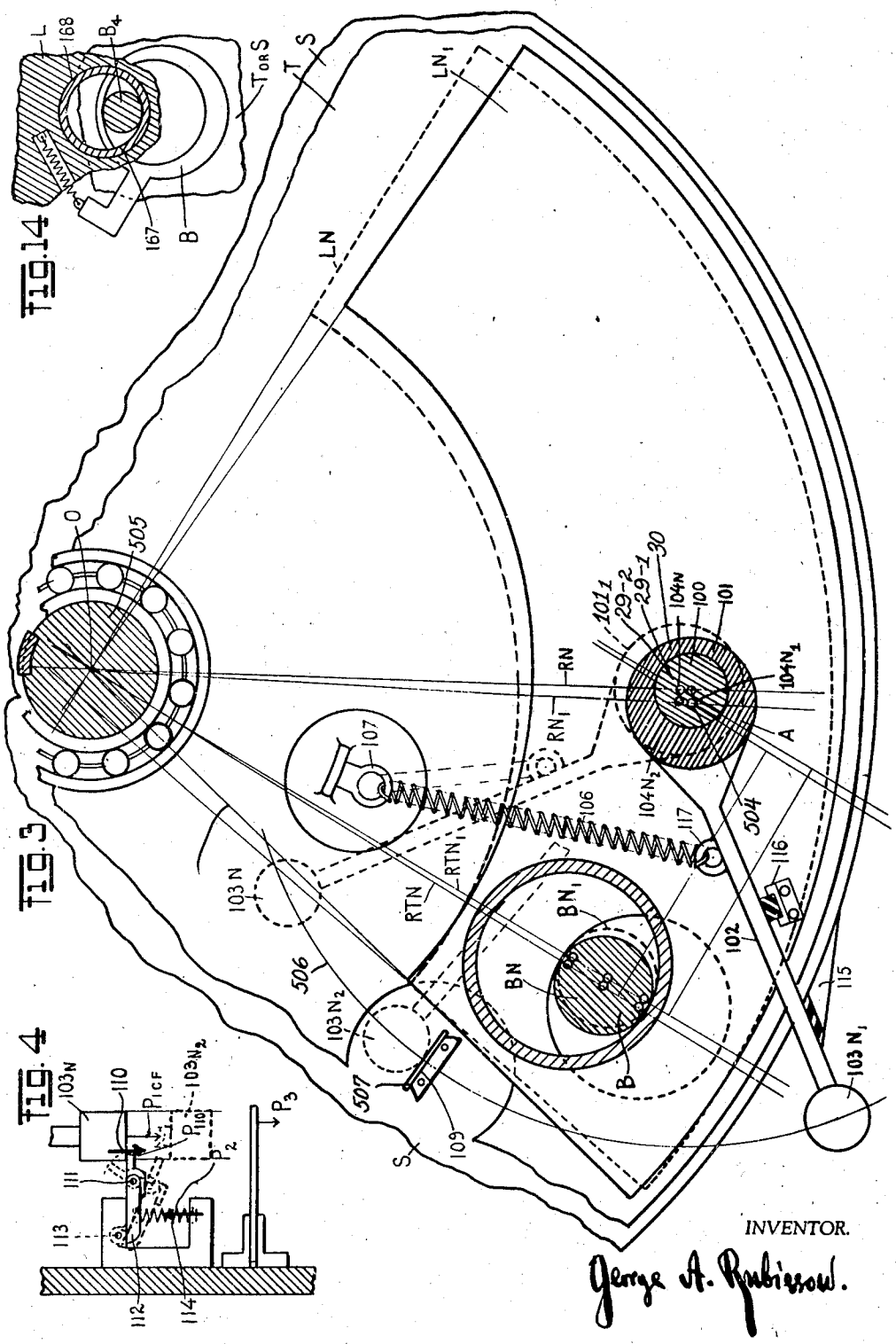


Fig. 3

Fig. 4

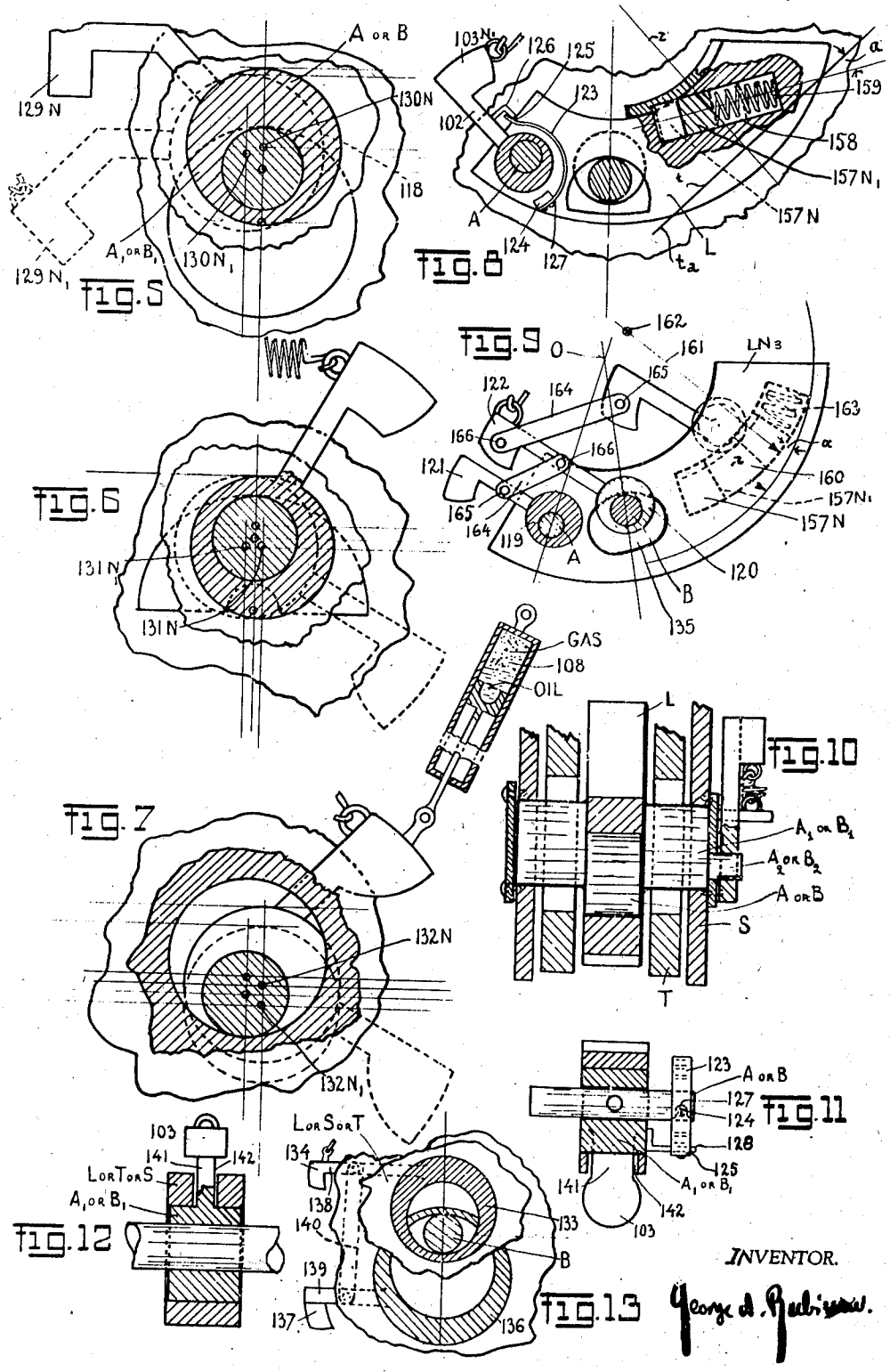
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SELF-TUNING POLYHARMONIC DAMPER

Filed March 8, 1941 3 Sheets-Sheet 3



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Patented Apr. 16, 1946

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UNITED STATES PATENT OFFICE

2,398,722

SELF-TUNING POLYHARMONIC DAMPER

George Alexis Rubissow, New York, N. Y.

Application March 8, 1941, Serial No. 382,383

7 Claims. (Cl. 74—574)

This invention is particularly applicable to the polyharmonic dampers as described in the Salomon patent applications Nos. 333,561 and 335,081, in which the following formula is given for the tuning condition calculation of a dynamic damper for a predetermined harmonic order n:

$$n^2=\frac{m.a.D.OK_1\ OK_2}{Mp^2.d.K_1\ K_2}$$

(theoretically for infinite inertia).

n=Harmonic order

m=Total mass of restoring levers

M=Mass of the disk

P=Radius of gyration of the disk (i. e., Mp^2= Momentum of inertia of the disk in reference to the axis O of the shaft)

W=The center of the pivot axle (see 29, Figures 1 and 2) of the device herein described, and for the purposes of simplification of the calculation, W is to be considered as being on the perpendicular at K_2 to OK_2.

$$K_1K_2=2(R_2-r)=\frac{1}{n^2}m.a.D.OK_1\ OK_2$$

(theoretically for infinite inertia).

For obtaining fictive inertia, infinite and positive (in reference to harmonic n)

$$R_2-r=\frac{1}{2n^2}\ \frac{m.a.D.OK_1OK_2}{Mp^2.d.1.02}$$

For obtaining fictive inertia, infinite and negative (in reference to harmonic n)

$$R_2-r=\frac{1}{2n^2}\ \frac{m.a.D.OK_1\ OK_2}{Mp^2.d.O.\ .98}$$

For obtaining other values for the fictive inertia (nil, positive or negative) (often in line motors), it is necessary to give other values to (R_2-r).

Figures 1 and 2 of this application show a front view and a cross-sectional side view, when regarding the engine rotating in the direction of the arrow F. It is very important, in all calculations of this condition of direction, to place the restoring levers so that while they turn in the direction of the rotation of the driving shaft, the center of gravity of the restoring lever, when pivoting, approaches the axis O of this shaft.

The above and further objects and novel features will more fully appear from the following detailed description when the same is read in connection with the accompanying drawings. It is to be expressly understood, however, that the drawings are for purposes of illustration only, and are not intended as a definition of the limits of the invention.

Fig. 1 shows a schematic plan view with parts broken out, of one embodiment of a damper partly in cross-section.

Fig. 2 is a cross-sectional view 2—2 of Figure 1.

Fig. 3 represents diagrammatic plan views partly in cross-section, with parts broken out, of a damper.

Fig. 4 is a diagrammatic side view, with parts broken out, of arresting means for the controlling weight controlling the position of the eccentric bushing-bearing member.

Figs. 5, 6 and 7 represent plan views, partly in cross-section, with parts broken out, of different arrangements of eccentric bushing-bearing members.

Figs. 8 and 9 represent plan views partly in cross-section with parts broken out of the lever provided with eccentric bushing-bearing members and additional weight, controlling the position of the center of gravity of the said lever.

Fig. 10 represents a cross-sectional side view, with parts broken out, of another embodiment of a part of a damper.

Figs. 11 and 12 represent, schematically, cross-sectional side views of an eccentric bushing-bearing member mounted in a lever or the like.

Figs. 13 and 14 are schematic plan views partly in cross-section, and with parts broken out, of eccentric bushing-bearing member provided with weights for controlling their position.

Figure 1 shows a damper having a member S rigidly affixed to the driven or driving shaft or to any other rotatable part of any machine. This member S may have any shape or form. In Figures 1 and 2, the member S is represented in the form of a circular flywheel, for purposes of convenience. On the said member S is mounted an oscillating mass T which is able to freely move around the shaft on which the member S is mounted. If desired, a bushing may be provided on the member S on which the oscillating mass T is mounted, preferably concentrically. This bushing is not shown on the drawings. If desired, a ball-bearing, needle-bearing, cylinder-bearing, etc. may be employed. The mass T is shown mounted concentrically in relation to the center O on Figure 1, and in relation to the axis XX of Figure 2. However, the member S may be provided with an eccentric bushing in relation to the axis (not shown on the drawings, being self-explanatory), in which case the opening of the oscillating mass T may also be eccentric to the axis XX.

The restoring member or levers L may be one or two symmetrically placed levers as shown in Figures 1 and 2, or any number of levers. Each lever L is provided with an opening or arcuate runway **24**. The oscillating mass T is provided with an opening or arcuate runway **26**. The member or lever L is operatively interconnected with the oscillating mass T through the intermediary of a pin or roller **28**. The member or lever L is further provided with a circular opening A_2E in which a pivot axle **30** is mounted, so that the lever may rotate limitedly around it. The pivot axle **29** or A may be affixed either rigidly or rotatably in the member S, for instance, by its ends **29—1** and **29—2**, as shown in Fig. 2.

The operation of this device has been fully described in the said two Salomon applications, Polyharmonic dynamic dampers, Serial Nos. 333,561 and 335,081.

One aspect of this invention comprises providing the lever L with an eccentric member A_2 having an interior circular opening $29A_1$ in which, or through which, the pivot axle **29** or A passes and which serves as a bushing or as a bearing for the said pivot axle. The outer circumference of the eccentric member A_2 is eccentric in respect to the center G of the pivot axle **29**. The eccentric member A_2 should preferably have its center of gravity GA_2 on the radius R_5 passing through the centers O and C. The centrifugal force will thus urge the eccentric member A_2 into such a position that its center of gravity GA_2 will lie on the radius R_5. Should the eccentric member A_2 for any reason be moved from the radius R_5, its center of gravity GA_2 will force it to return to its normal position. An arrangement such as this will permit the lever L to pivot around the pivot axle **29** or around the outer circumference of eccentric member A_2E, or simultaneously around both, or first partly around pivot axle **29** and then around eccentric member A_2E, or vice versa.

Owing to the fact that the harmonic order n also depends upon the distance d as per the formula herein given, any change in d either by way of being augmented or diminished, would change the harmonic order. This distance d is equal to WK_1 as shown on Fig. 1 (assuming W on the perpendicular at K_2 to OK_2).

It is evident that the action of the lever L will also depend on the possibility it has of rotating around the outer circumference A_2E of the eccentric member A_2, i. e., around the axis passing through the center CA_2, namely, rotate around another point W_1 instead of CA_2, thus augmenting the distance d in the arrangement as shown in Fig. 1, or diminishing the distance d if a suitable arrangement will be provided. This arrangement increases the polyharmonic tuning efficiency of the device herein described, and enables it to take care of several harmonics simultaneously. As a rule, in an engine with harmonic orders of 4, 5, 5½, 6½, 7 or 8, for example, this invention will first take care of the harmonics for which it is designed by choosing the relation between the pivot axle **29**, the pin **26** and the runways provided for the pin, and thereafter with the assistance of the eccentric member A_2, will take care of additional harmonics as well.

This invention comprises valuable improvements on the subject of the before-mentioned applications, providing an automatic control for the position which adjusts the polyharmonic damper of the character referred to, to a given order. Such automatic control utilizes the variation of the centrifugal force provided in the damper during its rotation at different speeds.

One of such improvements comprises means rigidly affixed to at least one of the eccentric bushing-bearing members, such means being a weight rigidly attached to said bushing-bearing members at a sufficient distance from their center of rotation, or mounted in said bushing-bearing members eccentric to their center of rotation, so that when the centrifugal force increases, the said bushing-bearing members will be urged by the centrifugal force created by the said weight. When the centrifugal force increases with the increase of the speed of rotation, it displaces the said weights and also turns the said eccentric bushing-bearings from one position to another, changing thereby the tuning conditions controlling the movement of the lever relatively to the shaft and to the other components of the damper.

One of such arrangements is schematically illustrated in Fig. 3, wherein the lever L is pivoted on a pin **100** on which the eccentric bushing-bearing member **101** is mounted, either rigidly or rotatably around it. An arm or pivot means **102** connects the eccentric member **101** with the weight $103N_1$. The lever LN_1 of such a polyharmonic damper is shown in dotted lines by LN in Fig. 3, in its non-operative position. Accordingly, in such a position the center 104_N of the eccentric bushing-bearing member 101_1 also shown in dotted lines, may be so chosen that prior to the rotation of the damper it takes the position as shown in Fig. 1, and as soon as the rotation of the damper begins, this center 104_N respectively takes a new position, for example, the position 104_{N1} (Fig. 3); because of the weight 103_N (shown in dotted lines) being urged by the centrifugal force from its position 103_N to the position 103_{N1}. It is advisable to provide the arm or pivot means **102** with resilient means **106** attached to a support **107** which may be rigid with the flywheel mass S of Fig. 1 or may be rigid with the free oscillating mass T of Fig. 1, or may be rigid with the lever L itself, as shown in Fig. 14. Such resilient means may be a spring **106** or a rubber, or a mixture of spring and rubber, or may be a pneumatic arrangement such as **108** for instance, as shown in Fig. 7. Instead of one spring, several springs may be employed simultaneously, operating by pull or push, or both.

One of the important aspects of this invention is the appropriate choice of the length of the arm **102**, and of the value of the weight 103_{N1} and of its shape and form.

From the aforementioned formula, the tuning order n is directly proportional in certain relations to a and D, or only a or only D, and is in reverse proportion to d (i. e., if the n order is increased). Should all other symbols of the formula remain the same, then:

(1) When n increases, a decreases, or
(2) n increases and D increases, or
(3) n increases, a and D both increase, or
(4) n increases, d diminishes, or
(5) n increases, a increases, and d diminishes, or
(6) n increases, D increases, and d diminishes.

In the case that n diminishes, vice versa relations will take place.

It may happen that, simultaneously, n will increase, a will slightly diminish, but D will augment sufficiently to compensate for the diminishing of a; or, it may happen that d will diminish to compensate for the diminishing of a. Several of

such eventualities for tuning the n order may take place, and this invention provides means to automatically tune the lever L in a given damper according to the order which has to be taken care of, i. e., eliminated or substantially eliminated at corresponding speeds.

It is not feasible to describe all the movements of the components of the damper necessary for accomplishing these results, and by way of example, the most characteristic one will be given.

In Fig. 3, the lever LN_1 is shown in its operative position in dotted lines LN, in which position it is maintained when the center 104N_1 of the eccentric bush-bearing member 101 lies on the radius RN_1. The eccentric bushing member may, by way of example, be composed (as shown in Fig. 2) from an axle 29—1, 29—2, on which the eccentricity making member 30 is mounted rigidly.

A lever 102 is rigidly mounted in respect to eccentricity making member 30. When 30 is rigid with the axle 29—1, 29—2, then the lever 102 may be mounted either on the member 30 or on the axle 29—1, 29—2. When the member 30 is not rigid with the axle 29—1, 29—2, then the lever 102 should be mounted rigidly on the member 30.

In its non-operating position, the lever LN_1 and the lever 102 to which a weight 103N_1 is attached occupy positions as shown in Fig. 3, such respective positions of lever LN_1 and lever 102 being controlled in particular by the position of the center of pivoting 504 of the eccentricity making member 30 around which the lever LN_1 is able to pivot.

The corresponding position of 504, for instance, will lie on the radii RN_1, when the lever 102 is in its lowest position as shown in Fig. 3.

The lever 102 may be provded with a weight 103N_1 and resilient means 106 operatively interconnecting the lever 102 through the attachment 117 with the attachment 107 rigid with the member S mounted rigidly on the main shaft 505 as shown in Fig. 3.

When the damper rotates with various speeds, the position of the weight 103N_1 will entirely depend on the resilience of the resilient means 106 and will take, for instance, the position 103N_1, when rotating at certain speed.

When non-rotating, the resilient means 106 will pull the lever 102 into the position 103N.

Thus, the center of pivoting 504 will respectively occupy the position from 104N_1 to 104N_2 to 104N, whereby the distance DN (i. e., the perpendicular from center 504 to the center of gravity GN of the lever LN_1) will change from DN to DN_1, displacing respectively, the center of gravity GN to the position GN_1, GN_3, and so on.

The difference between DN and DN_1, and so on, may thus be controlled by the angular displacement of the weight 103N_1 and of the lever 102 in regard to the center of pivoting 504 and thus, in order to provide a self-tuning damper, it will suffice to make such respective positions of the center of pivoting 504 and center of gravity GN correspond to the value n_1 in the tuning equation, such as given herein.

On its way from the position 103N to the position 103N_1 (i. e., from the position of rest of the damper to the position when it rotates at a certain speed) the lever 102 and the weight 103N will follow a predetermined pathway, for instance, 506 on Fig. 3.

It will suffice according to this invention, to provide means 109 as shown in Fig. 3, which may be of any kind and nature and, for instance, a resilient blade spring 507 or an arrangement as shown in Fig. 4, comprising a support on which a lever 112 is mounted on a pivot 113, the other end of said lever also having a pivot 111 on which is mounted another lever 110. The pivots and levers may be so arranged that when the weight 103N contacts the lever 110, it will compress the spring 114 having a predetermined resiliency to correspond to the centrifugal force to which such weight 103N will be subjected when it contacts the lever 110 at predetermined R. P. M. of the damper. Thus, only after the resiliency of spring 114 will be overcome could the weight 103N pivot the levers 110 and 112 and occupy the position 103N_2 for instance.

Such position-controlling means as 109 or as shown in Fig. 4 may be placed along the pathway 506 and may thus control more precisely the position of the lever 102, which will rest on such position-controlling means for as long as the corresponding R. P. M. of the damper will not exceed the predetermined ranges of value.

Thus, by way of example, at certain R. P. M., the pressure exercised by the weight 103N on the position-controlling means 109 may, for instance, be 140 pounds. Should we provide the resilient means of the blade spring 507, Fig. 3, or of the resilient means 114 of Fig. 4 to be greater than 140 pounds, say for instance 155, then the weight 103N and also the lever 102 will rest on such spring until the R. P. M. will be so big that the centrifugal pressure will become equal to 155 pounds. This is extremely important to prevent the undesirable pivoting of the lever 102 during the R. P. M. corresponding to the given centrifugal forces of 140–155, given purely for example only. It should be noted that such arresting position-controlling means as 109 and 507, Fig. 3, or as shown in Fig. 4, may be attached either to the member S or to the member T of Fig. 3. This requires only a reasonable skill of engineering.

The eccentric bushing-bearing members 30, 29—1, 29—2, may be provided as shown in Figs. 1, 2 and 3. In Figs. 5, 6 and 7 the eccentric 118 may be mounted either around 28 or B, or around the pin A (Fig. 2), or around both of them simultaneously. Such an arrangement is shown by way of example in Fig. 9, wherein the eccentric bushing-bearing member 119 is mounted around A and eccentric bushing-bearing member 120 is mounted around the pin B. Weights 121 and 122 control the automatic adjustability of such a lever, LN_3, and may be affixed through the corresponding arms or directly to the eccentrics 119 and 120.

In Fig. 3, only one eccentric bushing-bearing member in combination with axle is mounted around A as shown. However, the pin B may also be provided with one or two of such eccentrics as shown in Figs. 11, 12, 13 and 14.

Instead of resilient means 106, a spring-blade or the like 123 (Fig. 8) may be used if affixed rigidly by attachment 124 to the lever (or to the flywheel mass S or to the oscillating mass T) and contacting by its free end 125 the attachment 126 rigidly affixed to the arm 102 to which the weight 103N_1 is attached. Such type of spring 123 may also be employed with one end 127 (Fig. 11) attached directly to the pin A (or B) through suitable means 124—1, its free end 125—1 resting on attachment means 128 rigidly affixed to the eccentric member A_1 or B_1.

The initial position of the eccentric bushing-bearing member A_1 or B_1 as shown on Fig. 5,

may be so chosen that by movement of the weight 129_N to a position 129_{N1} the center around which the lever oscillates respectively, is moved from the position 130_N to the position 130_{N1}.

In Fig. 6 a similar arrangement is shown, but the center 131_N may be moved to position 131_{N1} at the same level so that the centers are displaced not vertically but horizontally.

In Fig. 7, the center 132_N may be moved to position 132_{N1} and provide a straight vertical displacement; a displacement, for example, along the radius passing through the center O (Fig. 3) of the rotation of the damper.

The eccentric members, as shown in Figs. 13 and 14, may also be employed if desired. In this case, the eccentric 133 cooperating with the pin B will be mounted in the lever L or flywheel mass or member S or oscillating mass T, and may be provided with arms or with weights 134 to control its positions. At the same time, the other eccentric members for the pin B may be either a simple opening 135 as shown in Fig. 9, or it may be an eccentric bushing-bearing member 136 (shown in Fig. 13), controlled by a special arm 139, together with the weight 137, if desired. Tuning of the lever may be controlled only by the weight 134 of the eccentric 133, in which case the arm 138 may be connected with the arm 139 through the intermediary of pivoted lever 140 or other articulated or flexible interconnection.

Still another embodiment of this invention is demonstrated in Figs. 11 and 12, wherein the eccentric members A_1 or B_1 are provided with arms 141 and the lever L (or T or S respectively) are provided with a slot 142 through which the arm 141 may pass. Such arrangements are particularly advantageous for economy of space.

Another important feature of this invention is to provide operative interconnection between the arms which operate the bushing-bearing member of the same dampers. For instance, in Fig. 9, the weights 121 and 122 controlling the eccentrics A and B, are operatively interconnected through articulated means 164 which are pivoted on pivots 165, 166. Any number of such articulated interconnections may be used to coordinate relative displacements of one bushing-bearing in relation to others.

Still another aspect of this invention is illustrated in Fig. 3A wherein the lever L_N is provided with a cutout 146 in which a mass 147 is mounted so that it can freely move along the said cutout. The lower surface of the cutout may follow a circumference 148 made with a radius from the center O or with any other suitable radius. The position of the mass 147 in the cutout 146 will vary the position of the center of gravity G_N of the lever L_{N1}. The mass 147 may be provided with means to control its position mechanically, hydraulically, pneumatically, electro-mechanically, or electro-magnetically, depending upon the speed of rotation of the device. These means may be operated voluntarily or automatically. Such automatic means consist of an arm 150 with a weight 149_N affixed to a gear 151 mounted on a shaft 152, which is mounted on the lever L_{N1}. When the weight 149_N moves into the position 149_{N1} it moves the mass 147 from its original position (shown by dotted lines) to the position as shown in solid lines by 147 in Fig. 3 and corresponding to the position 149_{N1} of the lever 150. Resilient means 153 may be provided to control the displacement of the mass 147 and to push it back when the damper reduces the speed or stops. In addition, resilient means 154 may also be provided to establish an opposing force of a predetermined value, which is able to pull back the weight 149_N and thus pull back the mass 147 from one position to another, as well.

Such control, as shown in Fig. 3A, permits the displacement of the center of gravity G_{N1} to a new position G_{N3}, thus augmenting the distance D_{N1} to the distance D_{N3} from the pivot A_7. The proper choice of augmentation or diminution of such distance will correspondingly influence the characteristics of the damper and thus take care of the harmonic or other disturbances corresponding, for instance, to the position of the center of gravity of D_{N3} or any other intermediate positions between D_{N3} or between D_N.

The mass 147 may also have the form of a cylinder 157, as depicted in Fig. 8, mounted in a cylindrical cutout 158 provided with resilient means 159. The inclination of the longitudinal axis of the cylinder 158 may be so chosen that there will be sufficient forces provided to control the displacement of the weight 157_N from its normal position 157_N to its operating position 157_{N1}.

In Fig. 9, this cutout may be cylindrical or have any other shape, for instance, 160, and follow a circumference made by the radius 161 drawn from the center 162, eccentric to the center O of the rotation of the shaft. The choice of this eccentricity gives the desired sensitivity for the displacement of the weight, taking into consideration the resilient means 163, which may be spring, pneumatic, hydraulic, or electro-magnetic.

In the case of controlling the center of gravity of the lever L by means of the displacement of the masses and weights such as 147 and 149_N (as shown in Fig. 3A), all desired predetermined positions of centers of gravity of the lever L_N may be predetermined accordingly and synchronized with predetermined speeds.

Still another aspect of this invention consists of providing, in the damper described, the lever of the type described, with self-adjustable weight of the type described herein for Figs. 8, 9. The arrangement such as the lever of Salomon provided with the free mass of Rubissow consists of providing in the mass of such lever, a cutout having a cylindrical or a square cross-section for example, at a certain angle α in respect to the tangent t_a, which is perpendicular to the radius r. The angle α may be very small and its choice dependent upon how much the chosen influence of the centrifugal force at certain speeds must displace the weight towards the part of the cutout which is at a further distance from the center of rotation of the damper than the former position of the weight in the same cutout. A spring 159 (Fig. 8) or 163 (Fig. 9) must be placed in the lower end of the cutout. During rotation of the damper, the spring is compressed by the weight to a predetermined degree, thereby controlling the position of the weight in the cutout at all speeds of rotation. The displacement of the position of the weight in the cutout permits the displacement of the damper's center of gravity from one position to another, and while this is accomplished automatically, as a function of the speed of the rotation of the damper, the automatic tuning capacity of the lever is thereby also controlled. Appropriate choice of the cross-section of the cutout, its length, the angle α, value of the weight and the force of the spring will be

necessary for proper control of the automatic tuning of the lever.

These arrangements may be employed without simultaneous use of the eccentric bushing-bearing member as described in this application. The cutouts may be of any shape or form and their longitudinal symmetry axis may also follow a circumference of a radius 162 (Fig. 9), for instance, which is concentric to the radius r. The angle a between the circumference of the radius 162 and the circumference of the radius r may be considered similar to the angle a of Fig. 8.

The movement of the weight may be towards the free end of the lever as shown in Figs. 8 and 9, or towards the center of the gravity of the lever. If desired, several cutouts may be employed simultaneously with several weights placed inside of them.

The resilient means, instead of being as shown in Fig. 8 and Fig. 9, may also be on both sides of the weight, one working as compressor and the other as a depressor. Only compressor or only depressor resilient means may be employed. Resilient means may be replaced by pneumatic piston-cylinder arrangement.

Another aspect of this invention provides a combined use of the described eccentric bushing-bearing member with or without arms, or with arms and weights, by operatively interconnecting such eccentric bushing-bearing members with the aforesaid weights of the character of weights or masses 147, 157N. This may be effected particularly by means of rigid interconnections, such as 164, Fig. 9, interconnected through the pivots 165 and 166, to the weights 144 (or directly to the eccentrics A and B, not shown on the drawings), or through pulley and flexible connections, gears, chains, "caterpillar" and the like.

Still another embodiment is illustrated in Fig. 14, having, in addition to the eccentric bushing-bearing member B, a cylindical bearing 167 which is mounted in a bushing 168 provided in the lever L. Such cylindrical bearing 167 will permit the pin B_4 to rotate while it is urged left or right, thus diminishing tangential frictional effort between the contacting surfaces of displacing parts.

Another, and one of the most important aspects of this invention provides voluntary consimultaneous use of the eccentric bushing-beartrol of the position of the eccentric bushing-bearing members. This is accomplished by an arrangement of levers, flexible interconnections, articulated means, pneumatic cylinder-piston devices, electro-mechanical or electro-magnetic means, with a collar-like member mounted on a shaft in such a way that when pushed to and fro longitudinally along the shaft, the position of the said bushing-bearing members is controlled. This voluntary control enables the operator of the engine to tune the damper at a given speed to a given sensitivity in advance, thus eliminating the undesirable torques or vibrations. This is extremely important and applicable to all engines where control of such disturbances is necessary.

Another aspect of this invention consists of means for voluntary control of the position of any eccentric bushing-bearing members described, provided with arms or with arms and weights and/or for controlling the position of the weights which are themselves provided with means to control and adjust the positions of the center of gravity of the counterweight or lever at predetermined values.

Such means will enable the operator to control the tuning order of the damper during its rotation. A synchronized speed-control device may also be employed if desired, for automatic control.

This invention is particularly important, inasmuch as it permits the tuning of this particular damper to any desired order or disturbing force of any nature. This latter aspect, as shown in Fig. 15, may be applied directly to the bushing-bearing members A or B or A_1, A_2 etc., or B_1, B_2 etc., or directly to the arms or means which control the position of the center of gravity of the lever. This means may also be applied in combination with automatic controlling means for the eccentric bushing-bearing members as herein described, in which latter case, their automatism will be controlled manually or by a synchronized controling device. This aspect permits the varying of the tuning of a resonance damper of the type described herein during the operation of the engine itself.

Fig. 15 represents the mass S (which may also be the free oscillating mass T or the lever L itself) in which the pin 463 rigid with the eccentric bushing-member 464 is mounted. A rigid arm 465 and a small axle 466 are rigidly affixed to the pin 463 or may be directly affixed to the eccentric 464 itself. A rigid connection in the form of a wire, bar, arm, chain or flexible cable 467 operatively interconnects the axle 466 with the pivot lever 468 which may be of any shape or form. Such interconnection is established by means of a pivot 469 or other suitable equivalent means, and by means of a pivot 170 on which the lever 468 pivots. The pivot 170 is mounted rigidly in respect to the shaft 171 by means of a girdle 172 rigidly attached to the said shaft. When the device rotates, the centrifugal force urges the arm 467 in the direction of the arrow 173. A controlling non-rotatable device 174 comprising a, preferably, well-polished plate or disk is mounted on a girdle or collar 175, provided on shaft 171 and able to slide to and fro thereon, guide means 176, one or more, may be provided in the frame, 177, which is rigid with the foundation or the ground or the chassis. When the controlling device 174 is pushed to and fro, it contacts the lever 468 in the surface 178 which surface itself is in constant contact with the disk 174 because of the rotation of the lever 468 with the shaft 171 and because of absence of rotation of the disk 174. By pushing the disk to and fro, the arm 167 of the lever 618 controls the position of the eccentric 164 to the desired value, thus controlling, as herein described, the characteristics of the damper and its tuning to the appropriate order. Means 179 may be provided to lock the position of the controlling disk 174.

All aspects herein described can be grouped in five different categories, as follows:

1. Dampers operated completely automatically by automatic tuning to the predetermined harmonic orders of the arms or arms and weights which control the eccentric bushing-bearing members A_1 and/or B_1 or which control the automatic adjustment of the positions of the centers of gravity of the lever or of the counterweight during the rotation of the damper.

2. Damper consisting means comprising voluntary control by the operator, of the position of the eccentric members A_1 and/or B_1, and/or of the position of the center of gravity of the lever or levers.

3. Dampers which consist of automatic control of the position of the eccentric members A_1 and/or B_1 by means of automatic synchronized

speed-controlling or speed regulating devices, such as described herein.

4. Dampers using a pneumatic control of the position of the eccentric members A_1 and/or B_1 or of the weights 147.

Having now ascertained and described the nature of the said invention and the manner in which it is to be performed, I declare that what I claim is the following:

1. A vibration or oscillation damper for a machine shaft comprising a first member rigidly mounted on said shaft, a second member mounted for movement about the axis of said shaft and said first member, at least one pivot means oscillatably mounted on said first member eccentrically to the axis of the latter, a lever mounted for oscillation about said pivot means eccentrically to the axis of said pivot means and the center of gravity of said lever, a first arcuate runway in said lever, a second arcuate runway in said second member, a pin of a radius smaller than the radius of curvature of either of said runways operatively connecting said lever with said second member, a solid weight eccentrically secured to said pivot means, resilient means adapted to resist movement of said weight in response to centrifugal force, said pivot means, weight, and resilient means cooperating to shift or adjust the pivot point of said lever relative to the center of gravity of the lever in response to centrifugal force, thereby tuning said damper to various orders of vibration.

2. A vibration or oscillation damper for a machine shaft comprising a first member rigidly mounted on said shaft, a second member mounted for movement about the axis of said shaft and said first member, at least one pivot means oscillatably mounted on said first member eccentrically to the axis of the latter, a lever mounted for oscillation about said pivot means eccentrically to the axis of said pivot means and the center of gravity of said lever, a first arcuate runway in said lever, a second arcuate runway in said second member, a pin of a radius smaller than the radius of curvature of either of said runways operatively connecting said lever with said second member, a solid weight eccentrically secured to said pivot means, resilient means adapted to resist movement of said weight in response to centrifugal force, said pivot means, weight, and resilient means cooperating to shift or adjust the pivot point of said lever relative to the center of gravity of the lever in response to centrifugal force, said damper further comprising means for supplementing or increasing resistance to movement of said weight in response to centrifugal force, said supplemental or increased resistance being applied at a certain point or at certain points in the path of movement of said weight, thereby tuning said damper to various orders of vibration.

3. A vibration or oscillation damper for a machine shaft comprising a first member rigidly mounted on said shaft, a second member mounted for movement about the axis of said shaft and said first member, at least one pivot means oscillatably mounted on said second member eccentrically to the axis of the latter, a lever mounted for oscillation about said pivot means eccentrically to the axis of said pivot means and the center of gravity of said lever, a first arcuate runway in said lever, a second arcuate runway in said second member, a pin of a radius smaller than the radius of curvature of either of said runways operatively connecting said lever with said second member, a solid weight eccentrically secured to said pivot means, resilient means adapted to resist movement of said weight in response to centrifugal force, said pivot means, weight, and resilient means cooperating to shift or adjust the pivot point of said lever relative to the center of gravity of the lever in response to centrifugal force, thereby tuning said damper to various orders of vibration.

4. A vibration or oscillation damper for a machine shaft comprising a first member rigidly mounted on said shaft, a second member mounted for movement about the axis of said shaft and said first member, at least one pivot means oscillatably mounted on said second member eccentrically to the axis of the latter, a lever mounted for oscillation about said pivot means eccentrically to the axis of said pivot means and the center of gravity of said lever, a first arcuate runway in said lever, a second arcuate runway in said second member, a pin of a radius smaller than the radius of curvature of either of said runways operatively connecting said lever with said second member, a solid weight eccentrically secured to said pivot means, resilient means adapted to resist movement of said weight in response to centrifugal force, said pivot means, weight, said resilient means cooperating to shift or adjust the pivot point of said lever relative to the center of gravity of the lever in response to centrifugal force, said damper further comprising means for supplementing or increasing resistance to movement of said weight in response to centrifugal force, said supplemental or increased resistance being applied at a certain point or at certain points in the path of movement of said weight.

5. A damper as set forth in claim 1 wherein said pivot means comprises a pivot-axle and an arm attached rigidly thereto, clearance means being provided in said second member around said pivot-axle to permit the movement of said second member around the axis of said shaft.

6. A damper as set forth in claim 3 wherein clearance means are provided in said first member around said pivot-axle to permit the movement of the said second member and said pivot-axle around the axis of said shaft.

7. A damper as set forth in claim 2 wherein said means for supplementing or increasing resistance to the movement of said weight in response to centrifugal force comprises at least one articulate member having resilient opposing means and mounted in the path of movement of a contact member rigidly attached to said weight to resist the movement of said weight as it pivots around said pivot means in response to said centrifugal force.

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