PUBLISHED
MAY 4, 1943.
BY A. P. C.

F. M. M. B. SALOMON

OSCILLATIONS REDUCING DEVICE

Filed May 6, 1940

Serial No. 333,561

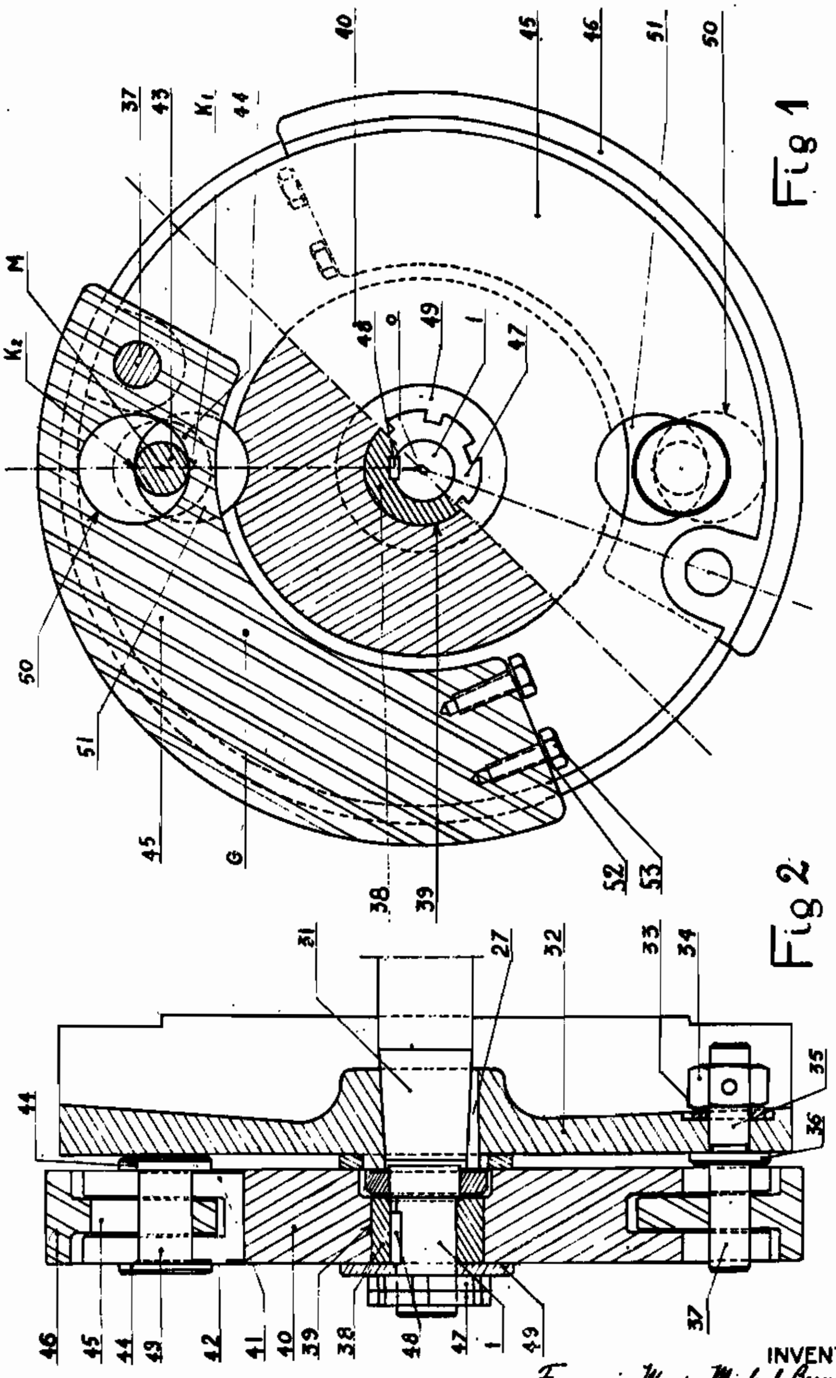

Fig 1

Fig 2

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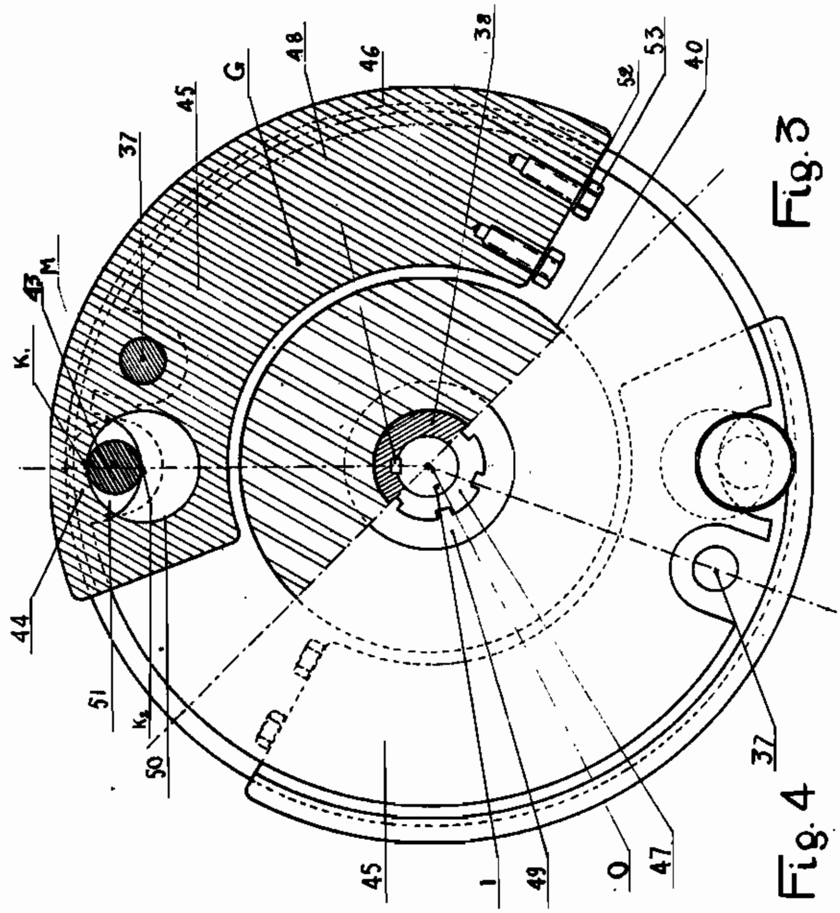

Fig. 3

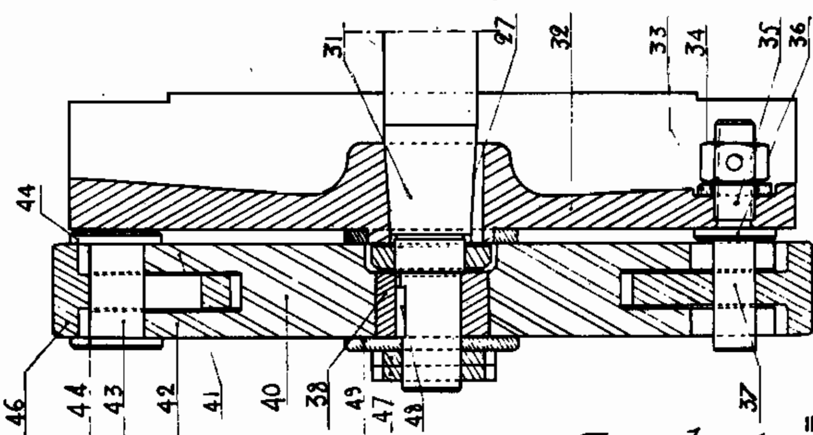

Fig. 4

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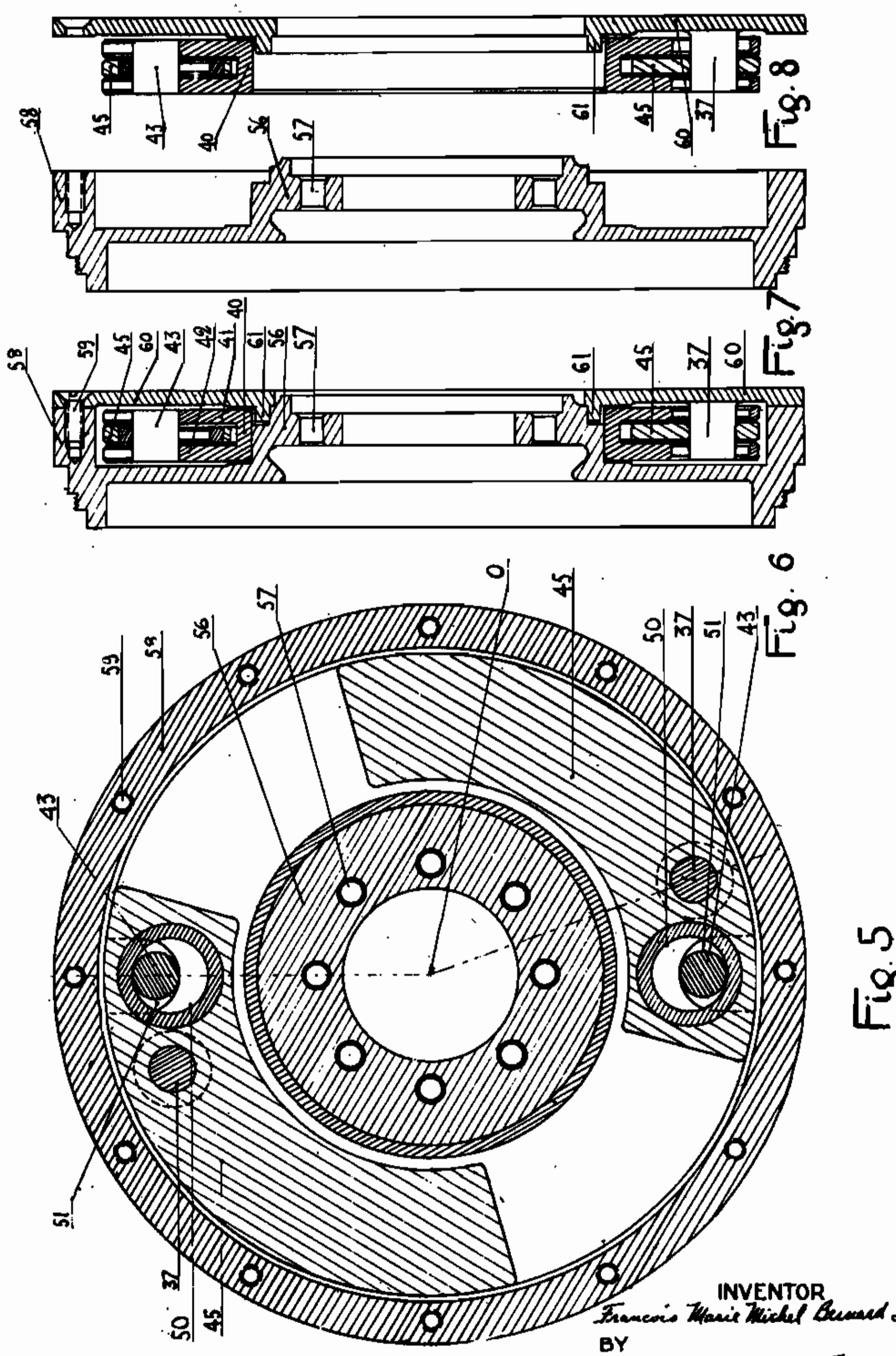

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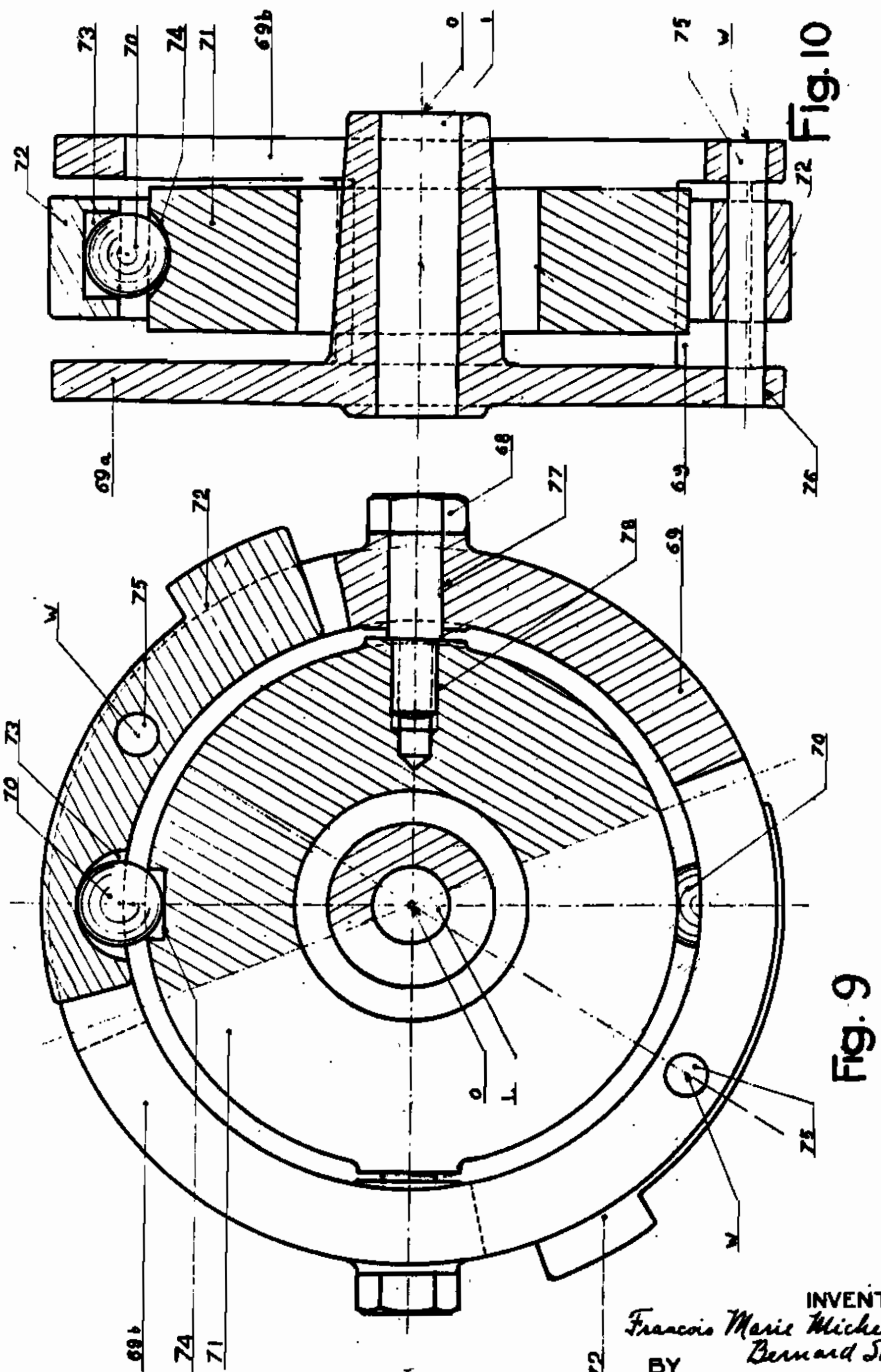
Serial No.
333,561
5 Sheets-Sheet 4



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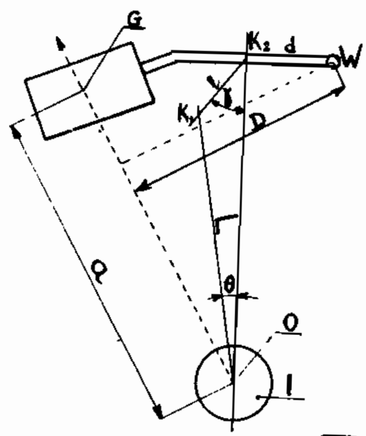

Fig 11

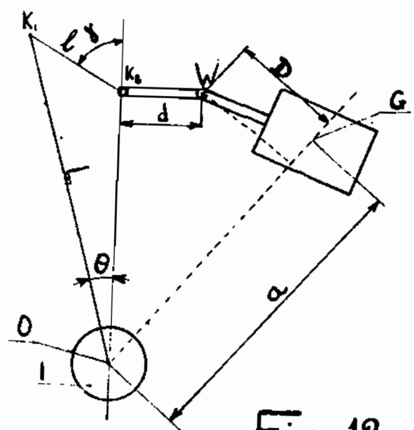

Fig 12

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Published May 4, 1943

Serial No. 333,561

ALIEN PROPERTY CUSTODIAN

OSCILLATIONS REDUCING DEVICE

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Application filed May 6, 1940

Devices for reducing oscillations in general and, in particular, in machine shafts, are already known, which utilize centrifugal pendulums: as it is known, the centrifugal pendulums are movable masses submitted at the same time to radial inertia forces (centrifugal forces) and to tangential inertia forces and which are rocking about their mean positions, under the restoring action of the centrifugal forces exerted on said masses.

My invention relates to quite different devices, in which centrifugal pendulums are not utilized.

In a device according to my invention, at least one oscillating member, rotatively carried with the shaft, and which is only substantially submitted to the tangential inertia forces and not to radial inertia forces (centrifugal forces), rocks under the action of disturbances and under the restoring action of at least one restoring member, acting as a restoring lever, rotatively carried with the shaft and which is only substantially submitted to the radial inertia forces (centrifugal forces) and not to the tangential inertia forces.

In those conditions, a device according to my invention utilizes mainly two kinds of members operatively interconnected: oscillating members, which are not centrifugal pendulums, as they are only substantially submitted to the tangential inertia forces and not to the radial inertia forces (centrifugal forces); and centrifugal restoring members, which again are not centrifugal pendulums, as they are not submitted to the tangential inertia forces but substantially only to the radial inertia forces.

It is important to make this second point quite clear: in devices utilizing centrifugal pendulums, those latter:

(1) Rock at the frequency of the disturbances;
(2) Rock about a mean position for which the restoring centrifugal torque is nil.

On the contrary, according to my invention:

(1) The oscillating motion of a restoring member is infinitely small during the oscillation motion of the "oscillating members" to which they are operatively connected. (In general, this oscillation angle is an infinitely small quantity of second order relatively to θ, if the oscillation angle of the "oscillating member" is called θ.)
(2) This extremely small oscillation motion occurs, not about the position for which the centrifugal torque being exerted on the restoring member is nil—as for pendulums—but, on the contrary, about a position for which this centrifugal torque is relatively big, and often nearly maximum.

So that the difference between the restoring members according to my invention and the centrifugal pendulums, is absolutely complete.

As it will be seen further on, great advantages are resulting from it, namely, because the devices according to my invention can be very favourably adapted for the elimination of all the harmonics, including the lowest and the highest, which is not the case in general for the devices utilizing centrifugal pendulums.

As to the shaft itself, it is not necessarily a shaft which must be preserved from vibrations; however, in many applications, it is just a said shaft.

The: "restoring members" can include—without exceeding the scope of my invention—elastic parts as: springs, yielding substances, plastic substances, fluids, etc. They include, in all cases, centrifugal elements.

However, more specially, there is an advantage to said "restoring members" including merely bodies submitted only, at least substantially, to the centrifugal forces created by the rotating shaft which carries them along.

The "restoring members" acting as restoring levers can be real levers or devices acting as such (eccentrics, cams, ramps, screws, etc.).

My invention is applicable to reducing speed oscillations, to the damping of torsional oscillations, flexional oscillations, lateral oscillations in any machine parts, and specially in machine shafts in all the sorts of engines, compression ignition engines, spark ignition engines, motor cars, compressors, ships, aeroplanes etc, etc.

The device can be put in any part of the machines, and, specially, of the engine shafts, for instance, at the front or at the rear of the crankshafts, in the balance-weights, even in the devices of connecting rods, in propeller hubs, etc.

It is often particularly advantageous to realize, more or less accurately, tuning conditions between the frequency of the disturbing forces and the natural frequency of the oscillating members, as it results of the action of the "restoring members."

In certain cases, this "tuning condition" can be made at the same time, not only, on one harmonic, but on two or several harmonics together, so that the same oscillating member—for instance, the same "harmonic disk"—can simultaneously eliminate the disturbances of two or several frequencies at the same time.

The connecting arrangement between the "oscillating members" and the "restoring members" and with the members carried along by the rotation of the shaft creating the centrifugal and restoring forces can be of any known type.

They can be provided with articulations, ordinary bearings, rolling members of various types, roller, ball, needle bearings, or surfaces rolling directly one on to another, with simple or double rolling.

The "oscillating members" can, in particular, be shaped like disks, fractions of disks, circular sectors, etc.

They ean be centered on the shaft or eccentric relatively to the axis of the shaft.

Even in this last ease, the working of the device is quite different from the one of the pendular systems, for the principle of the restoring forces is absolutely different.

As it has already been said, indeed, in the device according to my invention, the oscillating member has by itself substantially no restoring force, under the action of the centrifugal forces and the restoring force is entirely due or almost cntirely to the action of the restoring member.

The advantages of the devices which the invention has for its object relatively to the known devices, and specially to dampers utilizing centrifugal pendulums, are very considerable and that for many different reasons.

Those advantages can be substantially summed up as follows:

(1) They can be very easily adapted to the elimination of the lowest and highest harmonics.

(2) They are more efficient than the known dampers and, specially, than the dampers with centrifugal pendulums, in given conditions and for a given weight for the oscillating members:

(3) They enable to utilize to the best and, in the simplest conditions, the available room;

(4) The conditions of resonance are depending of numerous and very different factors, which gives great facilities;

(5) For given conditions, they are efficient until rotation speeds much lower that all known dampers.

(6) They avoid the use of noisy abutments and their working is always absolutely noiseless.

(7) They are of a very simple construction and of a very low cost price.

(8) They afford in a very simple and efficient manner the elimination of two or several harmonics, simultaneously, with only one oscillating member, and this often in better conditions than the known devices.

Certain constructions in accordance with my invention are, by way of example, illustrated diagrammatically in the accompanying drawings, of which—

Figures 1 and 2, represent respectively a front and a side-view of a first embodiment of the device; Figs. 3 and 4 are a second embodiment.

Figs. 5, 6, 7 and 8 are relative to a similar embodiment in the particular case when the device is mounted on an engine shaft for vehicle.

Figs. 9 and 10 represent respectively a front and a side-view of an embodiment of my invention applicable in the case when the oscillations to eliminate are flexional or lateral.

Figs. 11 and 12 are explanatory diagrams which bring into evidence the different lengths which intervene in the "tuning" conditions and, in particular, in the "resonance" conditions.

Figures 1 and 2 are respectively a front and a side view of a device according to my invention, mounted on a flywheel **32** keyed on, by a key **27**, on a shaft **31**, which will be, for instance, the shaft of an engine of a compression type, a spark ignition type, a compressor, a motor car or any vehicle, an aero engine, a propeller shaft, etc. (The hub propeller would then take the place of the web of flywheel **32**.)

In Figures 1, 2, the oscillating member is a disk **40**.

Said disk **48** is centered on shaft **31** through the intermediary of a ring **38**, (Fig. 2) which can be replaced by any bearing of a known type.

The ring **38** is itself fixed by the key **48** and by the nuts and lock-nuts **47**. The disk **40** has on its periphery, a crown-shaped cut of rectangular section, (Fig. 2) limited by two cheeks **41** and **42**.

In the cut, are placed two restoring levers **45**.

As to the cheeks **41** and **42**, they both present, at 180°, two cylindrical recesses **51** whereof the axis are K_1.

The restoring levers **45** are mounted on axis **37** forced into the flywheel **32** by their bearings **35**, with shoulders **38**, washers **33** and screws **34**.

Each restoring lever is crown-shaped and provided with a cylindrical recess **50** (Fig. 1) whereof the axis is K_2.

Those recesses correspond to the recesses of the disk **40**.

Two rollers **43**, whereof the cheeks are **44** and the axis M are passing through the recesses which are facing each other and so are at 180° one relatively to the other.

The action exerted by the centrifugal forces produced by the rotation of shaft **31**, gives, to the centre of gravity G (Fig. 1) of each restoring lever, a resultant tending to press each roller **43** between the ramps of the recesses of the disk and the ramp of the recess of the corresponding restoring lever.

The pins, whereof the shanks are **52** and the heads **53**, enable to insert at the extremeties of the restoring levers, additional masses, shaped like plates, to adjust to the best, in each case, the weight of each of these levers and the position of its center of gravity.

The working is as follows: under the action of the disturbances, the disk **40** rocks about its mean position and the restoring levers, through the intermediary of the rollers **42** exert a restoring action on it: indeed, under the action of the centrifugal forces, and through the intermediary of these rollers, these levers are always tending to draw the disk towards its mean position, position in which the axis K_2, M and K_1, are on the same geometrical radius.

The device represented in Figs. 3, 4, differs only from the previous one by the following fact: the restoring levers **45** are so arranged that, under the action of centrifugal forces, they are tending to press the rollers **43** between the ramps of the corresponding recesses, pushing back those rollers radially in the direction of the axis O of shaft **31**. On the contrary, in the device of Figs. **1**, **2**, the restoring levers **45** act on the rollers **43** by pulling: they are, indeed, tending to draw them radially in the opposite direction to the one of the axis O of shaft **31**.

The working is the same for the two devices, with the only difference that, in the first case, the restoring levers are acting on the rocking disk **40** drawing it towards its mean position and that, in the second case, the restoring levers are acting on this disk pushing it towards its mean position.

In the various cases, it is in general advantageous the axis of the restoring lever—i. e. the axis **37** in the previous figures—being substantially on the perpendicular at K_2 on the radius OK_2.

Figs. 5, 6, 7, 8 refer to a similar device, particularly intended to be fitted in a flywheel or in a vehicle engine clutch, motor car, for instance, or still in a ventilator pulley or against a pulley of an engine ventilator. The same device is applicable in the felloe of machine rotating members, aero engines, marine engines, compressors, propeller hubs, etc.

Fig. 5 is a front-view of a similar device to the one of Figs. 3 and 4; Fig. 6 shows a side-view of the same; Fig. 7 shows the rim of a clutch intended to receive the device; Fig. 8 is a side-view of the device before its mounting in the structure shown in Fig. 7.

The device being the same than the one of Figs. 3 and 4, the reference numbers are the same and a new description is useless. The only different parts are the following: in **56**, has been represented the central part of the web provided with holes **57** for assembling by bolts on the shaft, which has not been represented.

The peripheric part of the rim web has been represented at **56**.

In Fig. 6, the device is mounted on a plate **60** carrying the axis **37** of two restoring members, which are in this case centrifugal levers **45**.

This plate is also acting as a lid; it is fixed on the rim **58** by means of screws **59** and centered on the central part **56** by a bearing **61**.

Figs. 9 and 10 relate to devices for compensating disturbances which are parallel with the axis O of the shaft **1**, or which have a component which is parallel with said axis O (flexional oscillations, lateral oscillations).

Fig. 9 is a front-view, Fig. 10 a side-view.

The shaft **1** is secured by means of a web **69***a* to a felloe **69** provided with two cylindrical bearing holes **77** for two spindles **78** which are locked in a disk **71** capable of oscillating about said spindles on either side of the mean position shown in Figs. 9 and 10, responsive to the disturbances.

Nuts **66** ensure lateral guiding.

The device for restoring to the mean position comprises two opposite restoring levers, including centrifugal masses **72** and journals **75** whereof the axis are W, said journals participating in the rotation of the shaft **1** and the axis W performing a similar function to that of the axis **37** of the Figs. 1, 2, 3 and 4.

In the device of Figs. 9, 10, the restoring action of the levers, on the disk **71**, is effected through the intermediary of balls **70** which are clamped between a rolling surface **73** carried by the restoring lever and a surface **74** carried by the ring **71**.

Said surfaces could be spherical; they are cylindrical in Figs. 9, 10, with generatrices perpendicular to the plane of Fig. 9 for the surface **73**, and generatrices located in the plane of Fig. 9 for the cylinder **74**.

The center of gravity of each restoring lever is so arranged that each cylinder **73** presses against the corresponding ball **70**, which, in turn, presses against the cylinder **74** so as to push back the disk **71** to its mean position, when it moves away therefrom responsive to the action of the disturbances.

It would, on the other hand, be possible to use, with a slightly different embodiment the principle of restoring to the mean position by pulling as in Figs. 1 and 2.

The operation is similar to that described for the previous figures, which relate to devices intended to reduce oscillations of speed or torsional oscillations.

It has been well known, for at least twenty-five years, that in devices intended to reduce shaft oscillations, it is often advantageous that the rocking members have a natural frequency substantially equal to that of the disturbances to be compensated for.

It is quite obvious that the same applies in the case of the device of the present invention.

Figs. 11 and 12 are diagrams intended to make understood what are the dynamic and geometrical conditions to be realised for this purpose.

Fig. 11 relates to the case in which the restoring lever whereof the axis is W performs its function by extension, that is to say by pulling the oscillating member centered on the axis O towards its mean position.

Fig. 12 corresponds to the case in which the restoring lever whereof the axis is W acts, on the contrary by pushing back the oscillating member towards its mean position.

Fig. 11 shows, diagrammatically, the restoring system as equivalent to a restoring lever whereof the axis is W on which is articulated at K_2 a rod of length l, articulated, on the other hand at K_1, on an oscillating member, centered at O, having its center of gravity at O and capable of oscillating around the axis O, about its mean position (for instance, a disk like the disk **40** in Figs. 1, 2, 3, 4).

For this mean position, the point K_1 is on a straight line with points O and K_2.

The angle $\widehat{K_2OK_1}=\theta$ characterizes the angular displacement of the oscillating member relatively to its mean position.

The point K_2 remains substantially stationary, or, at any rate, its movements are infinitely small quantities of order 2.

The geometrical point W is on the perpendicular at K_2 to OK_2 (for the mean position of K_2), and it can be stated that:

$$WK_2=d$$

γ is the angle between K_2K_1 and OK_2.

G is the center of gravity of the restoring lever, including its centrifugal mass, and it can be stated that: $OG=a$.

m is the total mass of the restoring lever (or restoring levers).

M is the mass of the oscillating member centered on the axis O, (for instance, the disk 40 of figs. 1, 2, 3, 4).

ρ is its radius of gyration relatively to its center of gravity being supposed to be at O;

D is the distance from the point W to the line OG.

I have discovered that, relatively to the disturbing torque C sin wt having a pusation ω, the condition for resonance is substantially satisfied for all speeds of rotation of the shaft, if, by construction, the condition: $\Sigma=O$ is realised, by writing (u being the mean angular velocity of the shaft I):

$$\Sigma=\frac{u^2}{\omega^2}\,\frac{ma\frac{D}{d}.OK_1.\frac{OK_2}{K_1K_2}}{M\rho^2}-1 \qquad (1)$$

(the ratio: ω/u is often called the harmonic order n).

The equation (1) supposes that the following conditions are realised,

(1) The angles θ and γ are small and the movements of the restoring lever are negligible.

(2) Frictions are negligible.

(3) The only restoring forces are substantially the centrifugal forces which are exerting an action on the restoring lever.

The equation (1) applies also to the case of the diagram of fig. 12 on condition that K_1K_2 will be always considered in absolute value.

Finally, the equation (1) namely applies to the case of figs. 1, 2, and to the case of figs. 3, 4, or 5, 6, the structures of which are equivalent to the diagrams of figs. 11 or 12.

For $\Sigma=O$, everything takes place as if the moment of inertia of the entire rotating system were infinite. (Positively for Σ very small and positive, negatively for Σ very small and negative).

It may be advantageous, in various cases, to give Σ other positive or negative values, namely to avoid critical speeds.

Similar considerations and formulas, except for a few differences, apply to the case in which the system is intended to compensate for the components of disturbing forces which are parallel with the axis of the shaft I (which is the case of figs. 9, 10).

The fact that the oscillating member, which is more particularly disk-shaped, is, very often, tuned on a quite determinated harmonic to compensate, made me call those disks: "harmonic disks".

Besides, in various cases, it is possible, according to my invention, to tune the systems to more than one harmonic at the same time—that is why I have equally called those disks: "Polyharmonic disks".

In the various arrangements, it is often advantageous for the recesses, such as, for instance, the recesses 50 and 51 (fig. 1 or fig. 3,) or other recesses, performing a similar function, to be inwardly provided with a metallic rings, which will be, in general, of hard metal.

There is often an advantage to let those rings be loose in their recesses, or, at least, some of them, which enable them to have an oscillating movement. (Practically, this movement is extremely small).

Then they will be mounted with a very gentle friction in their housings. They could be mounted therein by means of special bearings (ball, roller, needle bearings, etc.).

The oscillating members (namely, harmonic disks) and the restoring members may be combined according to any other arrangement than those which have been shown in the accompanying drawings, and, in particular, according to any arrangement which would be equivalent, from a functional standpoint, to the diagram of fig. 11 or fig. 12.

In order to compensate for a plurality of different harmonics simultaneously, it is possible, instead of tuning only one oscillating system on several harmonics at the same time, to use a plurality of harmonic disks arranged parallel or still arranged in one and the same plane, (each of them being in this case reduced to only one sector), each of them compensating one harmonic only.

In the various cases, it is possible, to obtain a greater amplification of the restoring forces, by using two restoring levers or similar systems giving two successive amplifications of the restoring effects.

In the pendular centrifugal systems used as oscillating dampers, it is known that the pendular movement of a frequency f creates a perturbation of frequency $2f$, small in many cases.

In the systems according to my invention, this disturbance is also very small and even, in general, still smaller than in the pendular systems, if, preferably, a certain condition is observed, in reference with the direction of the rotating movement of the shaft.

This condition is to place the restoring levers so that, while they turn in the direction of the rotation of the driving shaft, (shaft 7 in the accompanying figures) the center of gravity of the restoring lever comes towards the axis O of this shaft.

Though the oscillatory movements of the oscillating members must preferably take place with little or very little friction, the scope of the invention would not be exceeded, if friction were introduced into said movements, by means of solids, fluids or otherwise, or still, if restoring springs were introduced.

Those springs could have a very small function or still a function of a substantial importance.

It is quite clear that the restoring levers may be of the most varied shapes and the expression: "restoring lever" is in no way limitative.

My invention concerns, in a general manner, any arrangement for the transformation of the restoring forces, whatever means may be employed (screws and nut systems, helicoidal ramps, etc.).

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