

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN ANTIVIBRATORY DEVICES WITH PHASE REVERSAL

(71) We, REGIE NATIONALE DES USINES RENAULT, of 8/10, Avenue Emile Zola, Billancourt (Hauts de Seine) France, and AUTOMOBILES PEUGOT, of 75, Avenue de la Grande Armée, Paris (France), both French Bodies Corporate, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to an anti-vibratory or vibration-damping device for fixed or movable engines or motors, which is applicable more particularly but not exclusively to motor vehicles.

This invention is concerned more specifically with a device for damping out a vibration generated by an engine or motor and transmitted directly to a surrounding frame structure or chassis through mounting blocks of elastic material which connect the engine to the frame or chassis, and is applicable more particularly to automotive vehicles and machine tools; this vibration damping device is designed for introducing into the frame structure, as close as possible to said engine mountings, a second vibration of same amplitude and frequency but opposite phase with respect to the first vibration, through a bar resiliently connected to the engine and to the frame, said bar supporting throughout its length an inertia weight adapted to be set in a selected adjustment position.

It is known that the vibrations of an engine are transmitted to the chassis, frame or like engine-supporting structure through elastic engine mountings. Certain known devices are capable of damping out the vibration of this structure, notably the device described in the French patent No. 1,520,695, which corresponds to the type of device referred to hereinabove.

This device comprises a rigid bar connected through elastic means such as rubber pads or shoes or coil springs at one end to

the engine and at the other end to the engine-supporting chassis or frame structure through the medium of resilient supports such as rubber pads or shoes, coil springs, etc. . . It is characterized by an essentially unidirectional compressibility. The bar is weighted by an inertia weight rigid therewith. With this device it is possible to return to the chassis, in a predetermined direction, a dynamic force of the same amplitude and frequency but opposite phase with respect to that introduced by the engine suspension. The setting and adjustment of the force thus introduced is achieved by shifting the weight so as to either properly select the bar inertia or adapting the stiffness to the single direction of operation of the previously selected resilient elements (rubber pads or shoes, coil springs, etc. . . . A proper balancing of the forces thus introduced requires that the point of application of the device to the chassis be as near as possible to the engine mounting or suspension.

This device, like other devices of the same character, provides a satisfactory operation in a specific direction. However, in most instances, it is highly desirable to reduce to zero the forces introduced into the structure along two perpendicular directions. In fact, in most machines and more particularly in internal combustion engines the force introduced into the structure does not keep the same direction at all times. As a rule, the structure is exposed to the action of a rotating force the characteristics of which depend not only on the vibratory movements of the engines, which are extremely complicated, but also on the specific properties of the engine suspension or elastic mountings. In all cases this force has components in two perpendicular directions.

It is the essential object of the device of the present invention to cancel or neutralize the two components of this force by resorting to an operation in two orthogonal directions. Thus, the force introduced into a predetermined plane, which may be referred to as the

operating plane, will be cancelled completely.

The invention provides apparatus for damping out a first vibration generated by an engine, comprising, in combination: an engine frame; elastic support means connecting said engine to said frame; and means for generating a second vibration having substantially the same frequency and amplitude as said first vibration but phase-inverted with respect thereto, said generating means comprising: a bar member; an inertia weight member mounted on said bar member and axially adjustable therealong; and means resiliently connecting said bar member to said engine and said frame, said resilient connecting means having anisotropic elastic properties which depend on the stiffness values of said connecting means along two orthogonal axes substantially perpendicular to the axis of said bar member, the anisotropic elastic properties of said connecting means being such that for each component of said first vibration in a plane perpendicular to the axis of said bar there corresponds a component of said second vibration which has the same frequency and amplitude as, but phase-inverted with respect to, said first vibration.

This invention and the mode of operation of the means constituting the subject-matter thereof will be better understood from the following description of a typical form of embodiment thereof which is illustrated by way of example in the attached drawing, in which:

Figure 1 is a perspective view of a vibration-damping device according to this invention, as applied to a motor vehicle;

Figures 2 and 3 are sectional views of a modified form of embodiment of the structure illustrated in Figure 1, namely a longitudinal axial section of the phase inverter and a cross section taken along the line III—III of Figure 2, respectively.

One of the elastic mountings 2 (for example a rubber block) of the engine 1 bears on the frame or chassis 3. The engine 1 generates both vertical and transverse vibratory movements, therefore the frame 3 will be vibrated through this suspension with a force F having two orthogonal components F_1 and F_2 . Force F_1 is directed in the direction A to compress the rubber block 2, and force F_2 is directed in the shearing direction B. The value and phase of each component force depend on the vertical and transverse vibrations of the engine, and also, of course, on the compression and shearing stiffness of the rubber material of these blocks. Thus, F_1 and F_2 are components in the directions A and B of the force F transmitted from the engine 1 to the frame or chassis 3.

The phase inverter device according to the present invention consists essentially of a bar 4 extending parallel to the longitudinal axis of the engine 1 and supporting an inertia

weight 5 shiftable along this bar. The latter is secured at one point of the engine through a rubber sleeve 6 having a stiffness k_1 in the direction A and a stiffness k_2 in the direction B. The other end of bar 4 is secured to the frame or chassis 3 through another rubber sleeve 7 having a stiffness k'_1 and k'_2 in the same reference directions A and B, respectively, this last-mentioned sleeve 7 being located in close vicinity of the engine suspension block 2. The anisotropy of the rubber sleeves 6, 7 is obtained by forming apertures 8 therein.

The movements of bar 4 are such that a force F' having components F'_1 and F'_2 in the reference directions A and B is introduced through the elastic member 7 into the chassis 3.

Considering the vibrations developed at points C and D of the engine and assumed to be in phase, the inertia weight, the bar dimensions, the stiffnesses k_1 and k'_1 in the direction A are selected to be such that the component F'_1 transmitted to the chassis 3 through the phase reversing device is of same amplitude and frequency as, and in phase opposition with, the force F_1 introduced into the chassis 3 by the engine suspension 2 in the direction A.

Similarly, the stiffness values k_2 and k'_2 of sleeves 6 and 7 in the reference direction B are so selected that the forces F_2 and F'_2 in the same reference direction B are in phase opposition and of same amplitude and frequency, i.e. modulus. The choice of rubber sleeves is not compulsory for these can be replaced by any other suitable system adapted to be assimilated in two orthogonal directions to a spring, for example resilient blades having a section such that the stiffness values in two perpendicular directions have the desired values, which in general differ according to each reference direction A or B.

At frequencies corresponding to said resonance frequencies, the vibration modulus may increase, instead of decreasing. As a rule, care is taken to place the highest resonance at frequencies where it is seldom attained or only at low intensity. On the other hand, the other resonance at a lower frequency may prove more detrimental. In order to eliminate the effect of this resonance without thereby affecting the efficiency of the system, the device of this invention may be supplemented with:

(1) a "beater" added to the inertia weight and tuned in the known fashion according to the following formula:

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{M}}$$

wherein:

f = resonance frequency of the beater,

k =coefficient characteristic of the stiffness of the rubber constituting the sleeve 9,
 M =mass of the beater ring 10 at a frequency very close to the lowest resonance frequency of the device which it is desired to eliminate.

The mass or inertia weight 5 is surrounded by a rubber sleeve 9 acting as a spring means and by a metal ring 10 constituting the beater (Figures 2 and 3). The resonator thus constructed affords a satisfactory attenuation of the low resonance frequency without impairing the efficiency of the phase inverter device which is the chief object of this invention, at frequencies higher than said resonance frequency.

Moreover, the rubber sleeve 9, like sleeves 6 and 7, may have an anisotropic structure so that two resonances can be attenuated in two operating directions by using the same beater.

(2) In case the sleeves 6 and 7 are replaced by resilient blades, this is achieved by employing a sandwich assembly comprising flexible metal blades separated by resin layers having vibration absorbing characteristics corresponding to the attenuation of the low resonance frequency.

In the case where in sleeves 6 and 7 of elastic material are used, the amplitude of the vibration corresponding to the low resonance frequency of the phase reversing device is obtained by utilizing a rubber composition known per se which comprises fillers capable of producing the maximum damping action in the frequency range concerned.

(3) An electromagnetic, pneumatic or mechanical device for locking the bar 4 when the engine speed is less than a predetermined threshold.

Means may be provided for discontinuing this locking action when said engine speed threshold, whereat the phase inverter becomes resonant, is overstepped. Beyond this limit, the phase inverter operates normally. This locking action may be controlled automatically by any part of the engine which is responsive to the r.p.m. value.

However, the above description is given by way of example only and should not be construed as limiting the field of the invention; for example, the position of the device may be changed without departing from the scope, as defined by the claims. In fact, the choice of this position is determined only by the plane in which it is desired to damp out vibration. Moreover, the number of such devices may correspond to the number of suspension devices or mountings utilized. Besides, the elastic elements may differ from those proposed and described herein, since they can also consist of elastic pads or blocks receiving stresses in two different directions.

The device according to the present invention improves considerably the attenuation or damping of engine vibration in comparison

with other similar devices, notably the device described in the prior French patent referred to above designed for damping out vibration only in a single direction. In contrast thereto, the present invention is capable of damping out vibration in a defined plane, due to its bi-directional mode of operation.

WHAT WE CLAIM IS:—

1. Apparatus for damping out a first vibration generated by an engine, comprising, in combination: an engine frame; elastic support means connecting said engine to said frame; and means for generating a second vibration having substantially the same frequency and amplitude as said first vibration but phase-inverted with respect thereto, said generating means comprising: a bar member; an inertia weight member mounted on said bar member and axially adjustable therealong; and means resiliently connecting said bar member to said engine and said frame, said resilient connecting means having anisotropic elastic properties which depend on the stiffness values of said connecting means along two orthogonal axes substantially perpendicular to the axis of said bar member, the anisotropic elastic properties of said connecting means being such that for each component of said first vibration in a plane perpendicular to the axis of said bar there corresponds a component of said second vibration which has the same frequency and amplitude as, but phase-inverted with respect to, said first vibration.

2. Apparatus for damping out a first vibration generated by an engine or motor according to claim 1, in which said resilient connecting means include elastomeric sleeve members disposed concentrically on said bar member and having cavities formed therein in at least one plane containing the axis of said bar member.

3. Apparatus for damping out a first vibration generated by an engine, according to claim 1, said resilient connecting means including blades having anisotropic elastic properties which depend on the stiffness values of said blades along two orthogonal axes substantially perpendicular to the axis of said bar member, said blades having such cross-sections that the stiffness values along said orthogonal axes differ from each other.

4. Apparatus for damping out a first vibration generated by an engine, according to claim 1 comprising means for attenuating the inherent resonance of said bar member and of said inertia weight member, said attenuation means comprising a beater in the form of a sleeve member having a ring-shaped weight fitted thereon and tuned to the frequency to be damped out.

5. The apparatus according to claim 4, wherein said sleeve member has weaker zones

k =coefficient characteristic of the stiffness of the rubber constituting the sleeve 9,
 M =mass of the beater ring 10 at a frequency very close to the lowest resonance frequency of the device which it is desired to eliminate.

The mass or inertia weight 5 is surrounded by a rubber sleeve 9 acting as a spring means and by a metal ring 10 constituting the beater (Figures 2 and 3). The resonator thus constructed affords a satisfactory attenuation of the low resonance frequency without impairing the efficiency of the phase inverter device which is the chief object of this invention, at frequencies higher than said resonance frequency.

Moreover, the rubber sleeve 9, like sleeves 6 and 7, may have an anisotropic structure so that two resonances can be attenuated in two operating directions by using the same beater.

(2) In case the sleeves 6 and 7 are replaced by resilient blades, this is achieved by employing a sandwich assembly comprising flexible metal blades separated by resin layers having vibration absorbing characteristics corresponding to the attenuation of the low resonance frequency.

In the case where in sleeves 6 and 7 of elastic material are used, the amplitude of the vibration corresponding to the low resonance frequency of the phase reversing device is obtained by utilizing a rubber composition known per se which comprises fillers capable of producing the maximum damping action in the frequency range concerned.

(3) An electromagnetic, pneumatic or mechanical device for locking the bar 4 when the engine speed is less than a predetermined threshold.

Means may be provided for discontinuing this locking action when said engine speed threshold, whereat the phase inverter becomes resonant, is overstepped. Beyond this limit, the phase inverter operates normally. This locking action may be controlled automatically by any part of the engine which is responsive to the r.p.m. value.

However, the above description is given by way of example only and should not be construed as limiting the field of the invention; for example, the position of the device may be changed without departing from the scope, as defined by the claims. In fact, the choice of this position is determined only by the plane in which it is desired to damp out vibration. Moreover, the number of such devices may correspond to the number of suspension devices or mountings utilized. Besides, the elastic elements may differ from those proposed and described herein, since they can also consist of elastic pads or blocks receiving stresses in two different directions.

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2. Apparatus for damping out a first vibration generated by an engine or motor according to claim 1, in which said resilient connecting means include elastomeric sleeve members disposed concentrically on said bar member and having cavities formed therein in at least one plane containing the axis of said bar member.

3. Apparatus for damping out a first vibration generated by an engine, according to claim 1, said resilient connecting means including blades having anisotropic elastic properties which depend on the stiffness values of said blades along two orthogonal axes substantially perpendicular to the axis of said bar member, said blades having such cross-sections that the stiffness values along said orthogonal axes differ from each other.

4. Apparatus for damping out a first vibration generated by an engine, according to claim 1 comprising means for attenuating the inherent resonance of said bar member and of said inertia weight member, said attenuation means comprising a beater in the form of a sleeve member having a ring-shaped weight fitted thereon and tuned to the frequency to be damped out.

5. The apparatus according to claim 4, wherein said sleeve member has weaker zones



in at least one plane containing one of its diameters.

6. The apparatus according to claim 1, further comprising means for attenuating the
5 inherent resonance of said bar member and of said inertia weight member, said attenuation means comprising sleeve members which contain a rubber composition containing
10 fillers to reduce the amplitude of vibration transmitted through said sleeve members at the resonance frequencies of said bar member and of said inertia weight member.

7. The apparatus according to claim 3, wherein said blades comprise a plurality of
15 superposed metal blades separated by layers

of a resin having vibration damping properties at the inherent resonance frequencies of said bar member and said inertia weight member.

8. Apparatus substantially as described
20 hereinabove with reference to and as shown in the accompanying drawings.

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