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(54) **Title**: A VIBROISOLATING DEVICE WITH A NONLINEAR FORCE VS. DISPLACEMENT CHARACTERISTIC AND A MOTOR VEHICLE SUSPENSION SYSTEM COMPRISING SUCH VIBROISOLATING DEVICE

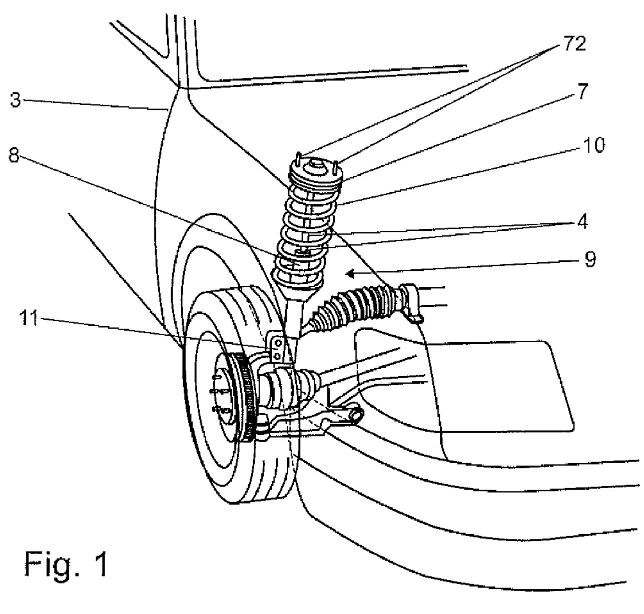

Fig. 1

(57) **Abstract**: A vibroisolating device (1) comprises a substantially elastomeric core (2) configured to be connected with a first displaceable object (3) and provide with an opening (21) configured to be connected with a second displaceable object (4). In order to obtain a nonlinear force vs. displacement characteristic of the device, substantially symmetrical around a certain and adjustable nonzero displacement value, the device (1) comprises at least one Belleville spring (5) disposed on the vibration transmitting path between said first displaceable object (3) and said second displaceable object (4), which is at least partially embedded in the volume of said substantially elastomeric core (2) and surrounds said opening (21). In particular the spring (5) is preloaded while said vibroisolating device (1) is in vibrations equilibrium position. The invention also relates to a motor vehicle suspension, in particular an adjustable active suspension system, comprising such a vibroisolating device.

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A VIBROISOLATING DEVICE WITH A NONLINEAR FORCE VS. DISPLACEMENT CHARACTERISTIC AND A MOTOR VEHICLE SUSPENSION SYSTEM COMPRISING SUCH VIBROISOLATING DEVICE

Technical Field

The present invention relates to a vibroisolating device with a nonlinear force vs. displacement characteristic, as well as a motor vehicle suspension system comprising such a device. In particular the invention relates to a vibroisolating device comprising a substantially elastomeric core configured to be connected with a first displaceable object and provided with an opening configured to be connected with a second displaceable object.

Background of the Invention

Various solutions for isolating vibrations are known from the state of art. They usually involve elastomeric materials and in automotive applications vibroisolating devices are employed usually in engine mounts and suspension module top mounts. Their general aim is to ensure low stiffness to efficiently isolate small amplitude vibrations around a certain equilibrium point, while at the same time provide high stiffness for high stroke vibrations to transmit mutual displacements of displaceable objects.

Patent specification US 5,271,595 discloses a resilient support device having a non-linear elastic characteristic, that comprises a body of resilient material provided with two members, coupling the device with a support and a mass to be supported, which are resiliently linked together by two relatively rigid branches, which in turn are connected to each other by at least one resilient crosspiece that is prestressed in traction and is designed to buckle when the forces acting between the coupling members reach a predetermined value, wherein the deformation of the crosspiece(s) is suddenly stopped by an abutment system of relatively high stiffness. The device is applicable as an exhaust pipe support.

Patent specification US 4,984,777 discloses a flexible bearing for supporting a body, such as an internal-combustion engine, that includes a journal bearing that may be attached to a supporting foundation and a support that may be attached to the engine. An elastic spring is connected between the journal bearing and the support while a bearing spring made of a non-creeping material is connected between the journal bearing and the support in parallel with the elastic spring. The bearing spring comprises at least one disk spring having an S-shaped spring constant curve. The disk spring and the elastic spring have load carrying capacities such that, after the weight of the body to be supported is applied to the flexible bearing, the spring rate of the disk spring is essentially zero and the rubber spring is essentially free of elastic tensions.

Other supporting systems are known for example from patent specifications US 5,310,157, DE 3637294 A1, JP 2000-266118, JP 2009-085300 and DE 3608934 A1.

There is an object of the present invention is to provide a vibroisolating device featuring nonlinear force vs. displacement characteristic, substantially symmetrical around a certain and adjustable nonzero displacement value, which might correspond to an equilibrium point of vibrations.

Another object of the present invention is to provide a vibroisolating device which could be employed in a vehicle hydraulic damper, in particular an adjustable active suspension damper, which would effective compensate predefined preload of the damper and would feature relatively high and low stiffness respectively for high and low amplitude vibrations.

<u>Summary of the Invention</u>

In order to accomplish the aforementioned and other objects, the invention provides a vibroisolating device of the kind mentioned in the outset which additionally comprises at least one Belleville spring disposed on the vibration transmitting path between said first and said second displaceable objects, wherein said at least one Belleville spring is at least partially embedded in the volume of said substantially elastomeric core and surrounds said opening.

The presence of the spring within the volume of the core alters the uniformity (isotropy) of the core block and differentiates its reactions with regard to opposite displacements perpendicular to the plane of the spring.

The term "elastomer" or "elastomeric" according to the present invention refers to any material capable of storing strain energy thermally within its volume.

Preferably said at least one Belleville spring is preloaded while said vibroisolating device is in its equilibrium position. In fact predefined or assumed preload of the spring enables to bring the vibroisolating device into an equilibrium position.

Preferably the device further comprises a substantially stiff support disposed within said opening of the core and provided with means for connecting said second displaceable object. Said support improves interception of vibrations of this second displaceable object.

Further the vibroisolating device according to the invention preferably comprises a housing at least partially surrounding said core and provided with means for connecting said first displaceable object. The housing enables for convenient integration of the device with the first displaceable object.

In such a case it is advantageous if said core is compressed within the housing. The compression makes it possible to define desired pretension of the core and thus the characteristic of the device as a whole.

Preferably said core is axially unsymmetrical. Such an asymmetry enables for further differentiation of the reactions of the device with regard to displacements along various directions.

Preferably said at least one Belleville spring is a conical spring, a wave spring or a perforated conical spring. Construction of the spring is another factor enabling for defining the device 3D stress–strain characteristic.

In some embodiments it may be advantageous to provide the vibroisolating device with a number of Belleville springs separated and/or forming a stack. A number of springs may be advantageous to provide an appropriate spring constant of such a set of springs if application of one spring is impossible for example due to design or geometric restrictions.

The vibroisolating device according to the invention is particularly applicable as a part of the vehicle suspension where said second displaceable object is a piston rod of a hydraulic damper.

Accordingly the invention provides also a motor vehicle suspension, and in particular an adjustable active suspension system, comprising a vibroisolating device as defined above.

Brief Description of the Drawings

The other features of the invention shall be presented below in exemplary embodiments and in connection with the attached drawings on which:

Fig. 1 schematically illustrates a front right motor vehicle suspension that has been provided with a vibroisolating device according to the invention;

Fig. 2 is a side cross-sectional view of a top mount of the vehicle suspension shown in Fig. 1 in an unloaded position along the plane parallel to the vehicle regular driving direction;

Fig. 3 is an axonometric view of a vibroisolating device shown in Fig. 1 extracted from the suspension top mount;

Figs. 4a and 4b illustrate the displacement range of the top mount shown in Fig. 1 between a compression position (left side) and a rebound position (right side) with respect to the mechanically preloaded initial position (spring depicted by dashed line);

Figs. 5a and 5b illustrate the characteristic of a force vs. displacement of an elastomeric vibroisolator known from the state of art (fig. 5a) and a vibroisolator according to the present invention (fig. 5b);

Figs. 6a and 6b show another embodiment a vibroisolating device according to the present invention employed as a standalone support of a body, for isolating vibrations transmitted in a vertical direction and loaded gravitationally by this body, in a cross-sectional and axonometric view respectively; and

Figs. 7a, 7b and 7c show exemplary constructions of Belleville spring applicable in the vibroisolating device according to the present invention.

Fig. 1 schematically illustrates a fragment of an exemplary vehicle suspension 9 attached to a vehicle chassis 3 by means of a top mount 7 and in particular by means of a number of screws 72 disposed on the periphery of the upper surface of the top mount 7. The top mount 7 is connected to a coil spring 10 and a rod 4 of a hydraulic damper 8. The tube of the damper is filled with working fluid inside of which a piston assembly attached to the piston rod 4 led outside the tube is slidably disposed. At the other end the damper tube is connected to the steering knuckle 11 supporting the vehicle wheel. All the above features are well known to those skilled in the art.

The suspension serves a dual purpose of improving the friction between the road surface and the wheels of the vehicle and at the same time of improving the overall harshness and vibroacoustic comfort for the vehicle passengers. To improve the suspension characteristics an adjustable active suspension has been recently proposed. This approach utilizes monotube dampers charged with gas, the pressure of which acts on the piston rod 4 pushing it upward. This preload along with a gravitational preload of the vehicle chassis 3 must be handled by the top mount 7.

Fig. 2 illustrates the cross-section of the top mount 7 shown in Fig. 1. The main purpose of the top mount 7 is to isolate vibrations transmitted from the piston rod 4 to the top mount 7 housing and therefrom to the vehicle chassis 3 (cf. Fig. 1). To this end the top mount 7 must provide low stiffness for small displacements of the piston rod 4, while on the other hand, for higher amplitudes of the piston rod 4 strokes, higher stiffness of the top mount 7 is required to in order to control the dynamics of the vehicle chassis 3 by appropriate transferring forces from a damper.

The top mount 7 is formed by two coaxially arranged cup-shaped, stamped covers 73 and 74 provided with circumferential flanges 75, 76 that are fixedly connected to each other. The flanges 75 and 76 are provided around the periphery with a number of vertical through openings 71 to attach the top mount to the vehicle chassis 3. Further the flanges 75 and 76 support the coil spring 10.

The covers 73, 74 form a chamber inside of which a vibroisolating device 1 is disposed. The device comprises a substantially cylindrical core 2 made of synthetic silicone rubber of predefined elastic properties and geometry, that has been pressed inside this chamber.

The core 2 is provided with an opening 21 inside of which a steel, substantially cylindrical support 6 is disposed. The support 6 is provided with a flange 61 enabling for connecting the piston rod 4 having its axial projection 41 led through the flange 61 and screwed at the other end by a nut 42.

The core 2 surrounds the support 6 with its circumferential flanges 23, 24 which improve interception of the axial displacements of the support 6 along the axis of the piston rod 4 relative to the top mount 7.

Further the core 2 is also provided with stops 77 for the compression stroke projecting equiangularly around the bottom surface of the core. Obviously it is possible to provide the top surface of the core with similar stops for the rebound stroke.

The top mount 7 shown in Fig. 2 is in an unloaded position that is before preloading the vibroisolating device 1 with the upward pressure of the piston rod 4 and downward directed weight of the vehicle chassis.

In the volume of the core 2 a Belleville conical spring 5 of predefined elastic properties and geometry has been embedded during molding the core 2. The spring 5 is arranged in such a manner that its inner circumferential edge is directed towards the damper 8 tube. The spring alters the isotropy of the elastic properties of the core along the longitudinal axis A which shall be explained later in particular with reference to Fig. 5. In this embodiment the spring 5 has not direct contact with the support 6 or the internal surface of the chamber formed by the covers 73 and 74.

Further as shown in Fig. 2 and Fig. 3 the axial symmetry of the core 2 is disturbed by two cavities 22 extending along the lines B perpendicular to the axis of symmetry A of the core. The cavities also alter the isotropy of the core along the line C that is orthogonal to the lines A and B to provide lower stiffness of the device along the vehicle longitudinal chassis (i.e. along the vehicle regular driving direction) which is beneficial, e.g. while driving on a rough surface.

Fig. 4 illustrates operational range of an embodiment of the suspension top mount 7 shown in Fig. 1 between a compression position (Fig. 4a) and a rebound position (Fig. 4b).

After assembling the suspension damper 9 the top mount 7 is preloaded by the fraction of the weight of the vehicle and, if active, precharged suspension is employed, also by the pressure of the piston rod 4 that pushes the support 6 upward causing a deflection of the spring 5 which takes the horizontal position illustrated by dashed line on Figs. 4a and 4b. In this embodiment this position of the spring 5 corresponds to the vibroisolating device 1 equilibrium position that is the position of the vehicle at rest, nominally loaded and standing on a horizontal flat surface.

Further movement of the rod 4 above the equilibrium position (a compression stroke, Fig. 4a) will cause the spring 5 to deflect upwardly, while the movement below the equilibrium position (a rebound stroke Fig. 4b) will cause downward deflection of the spring 5. It shall become more apparent with reference to the following description.

Fig. 5a illustrates the stiffness characteristic of a typical vibroisolator comprising solely an elastomeric core. As shown, two ranges can be distinguished within the characteristic: "low stroke–low stiffness" range that would provide good isolation for engine vibration and road harshness, and "high stroke–high stiffness" range where damper forces should be transferred for the vehicle chassis to improve the vehicle control and dynamics. The "low stroke–low stiffness" range is generated by shear of the elastomeric core section at small strokes within +/- 1 mm range, while the "high stroke–high stiffness" range is generated by compression of elastomeric core above this limit.

Neglecting certain hysteresis, the stiffness characteristic of the vibroisolator is symmetrical around an equilibrium position corresponding to zero displacement between both displaceable objects connected to the vibroisolator i.e. the piston rod 4 and the vehicle body 3. Unfortunately such an equilibrium position or zero displacement rarely happens in reality since the vibroisolator is initially preloaded at least gravitationally by the weight of the body that it supports, which in turn shifts the equilibrium position upwardly into a certain position denoted as "new equilibrium position". This preload (and corresponding shift) is additionally increased in case of gas preloaded dampers of adjustable active suspension systems. Consequently vibrations (oscillations) about this new equilibrium position will no longer induce desired force response of the isolator but will generate uncomfortable high forces for small rebound (upward) displacements and undesirably small forces for small compression (downward) displacements.

Fig. 5b illustrates the stiffness characteristic of an embodiment of a vibroisolator according to the present invention. As shown, the presence of the Belleville spring embedded in the volume of the elastomeric core shifts the whole characteristic to the equilibrium position that corresponds to the relative displacement between both displaceable objects which is generated by their relative preload. This is due to a complex three-dimensional stress state within the core since the longitudinally asymmetric spring moulded within the core generates a response while preloaded into the equilibrium position of the system. In other words the spring exceeds its stability range and act "against" the stiffness of the elastomer. Combined stiffness of the system results in characteristic shown in Fig. 5b.

Obviously by changing the elastic properties of the spring or springs moulded in the vibroisolating device it is possible to freely adjust (shift) the equilibrium position with respect to assumed preload and other factors.

Figs. 6a and 6b illustrates another embodiment of the vibroisolating device 1a in a form of an isolating support of another vibrating device (not shown) such as an electric motor or a household appliance (refrigerator, washing machine, etc).

In this embodiment no housing surrounding the core is provided and the first displaceable object is simply the surface 3a that supports the device 1a. A leg 4a of the vibrating device (second displaceable object) is inserted into a cup-shaped support 6a disposed within an opening 21a and fixed to a rubber, cuboidal core 2a. Further the core 2a is provided with three conical spring washers 5a moulded within the core volume and arranged coaxially one above the other, wherein the two uppermost springs additionally form a stack. The parameters of the washers are chosen to compensate the gravitational preload caused by the weight of the vibrating device transmitted by the leg 4a to the base surface 3a.

Figs. 7a, 7b and 7c shows some examples of Belleville spring i.e. a conical spring 5b, a wave spring 5c and a perforated conical spring 5d.

The parameters of the spring are preferably chosen in such a manner that after moulding within the core a preliminary load will lead to deformation of the spring to the shape of a flat washer the plane of which is substantially perpendicular to the longitudinal axis of the vibroisolating device.

The above embodiments of the present invention are merely exemplary. The figures are not necessarily to scale, and some features may be exaggerated or minimized. These and other factors however should not be considered as limiting the spirit of the invention, the intended scope of protection of which is indicated in the appended claims.

What is Claimed is:

1. A vibroisolating device (1) comprising
a substantially elastomeric core (2) configured to be connected with a first displaceable object (3) and provided with an opening (21) configured to be connected with a second displaceable object (4),
characterized in that
it additionally comprises at least one Belleville spring (5) disposed on the vibration transmitting path between said first (3) and said second (4) displaceable objects, wherein said at least one Belleville spring (5) is at least partially embedded in the volume of said substantially elastomeric core (2) and surrounds said opening (21).

2. The vibroisolating device according to claim 1, characterized in that, said at least one Belleville spring (5) is preloaded while said vibroisolating device (1) is in vibrations equilibrium position.

3. The vibroisolating device according to claim 1 or 2, characterized in that, it further comprises a substantially stiff support (6) disposed within said opening (21) of the core (2) and provided with means (61) for connecting said second displaceable object (4).

4. The vibroisolating device according to claim 1 or 2 or 3, characterized in that, it further comprises a housing (7) at least partially surrounding said core (2) and provided with means (71) for connecting said first displaceable object (3).

5 The vibroisolating device according to claim 4, characterized in that, said core (2) is compressed within the housing (7).

6. The vibroisolating device according to any one of the preceding claims, characterized in that, said core (2) is axially unsymmetrical.

7. The vibroisolating device according to any one of the preceding claims, characterized in that, said at least one Belleville spring (5) is a conical spring (5b), a wave spring (5c) or a perforated conical spring (5d).

8. The vibroisolating device according to any one of the preceding claims, characterized in that, it comprises a number of Belleville springs (5a) separated and/or forming a stack.

9. The vibroisolating device according to any one of the preceding claims, characterized in that, said second displaceable object (4) is a piston rod (4) of a hydraulic damper (8).

10. The vibroisolating device according to any one of the preceding claims, characterized in that, it consist a part of a motor vehicle suspension (9).

11. A motor vehicle suspension system characterized in that, it comprises a vibroisolating device (1) defined in any one of the preceding claims.

12. The motor vehicle suspension system according to claim 11 characterized in that, it is an adjustable active suspension.

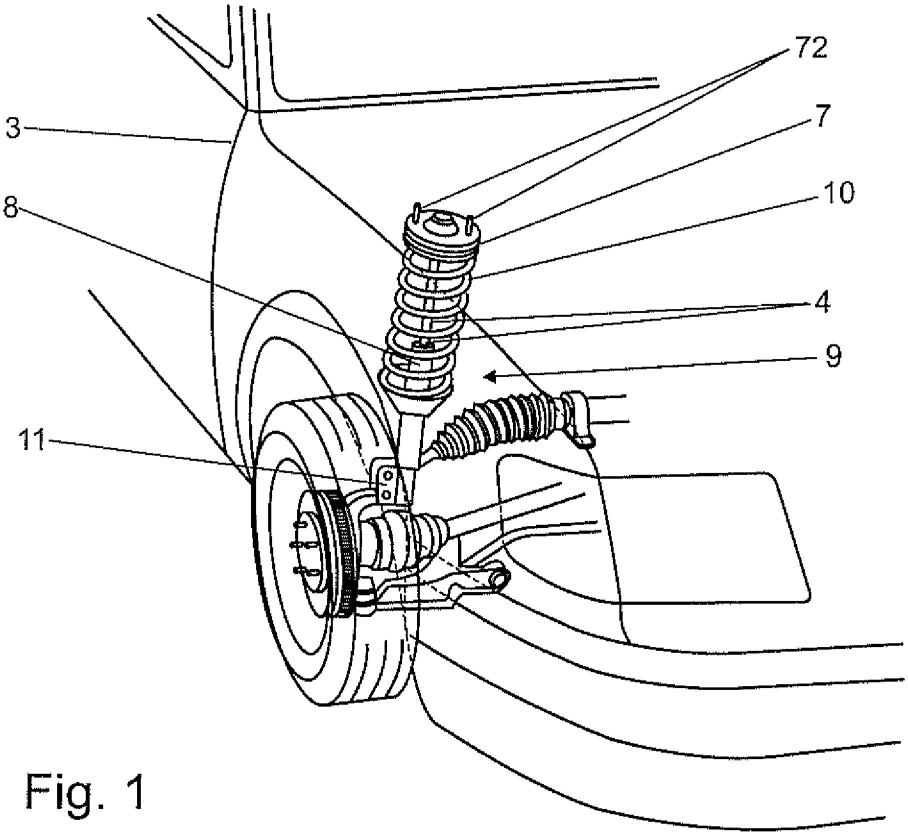
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Fig. 1

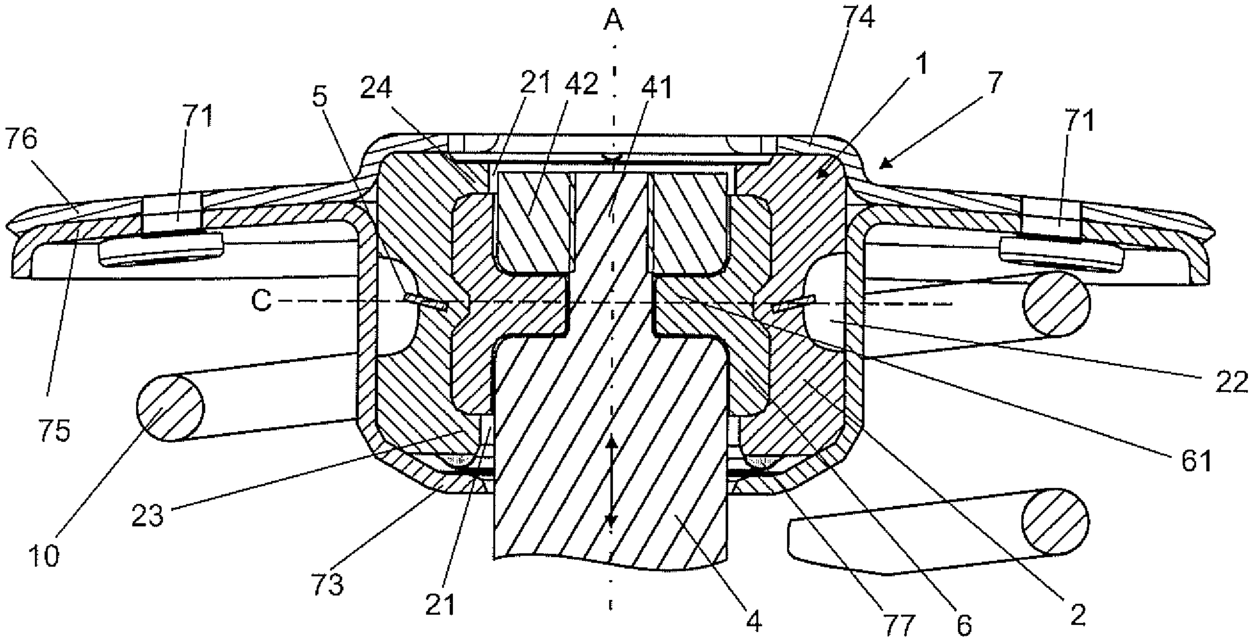
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Fig. 2

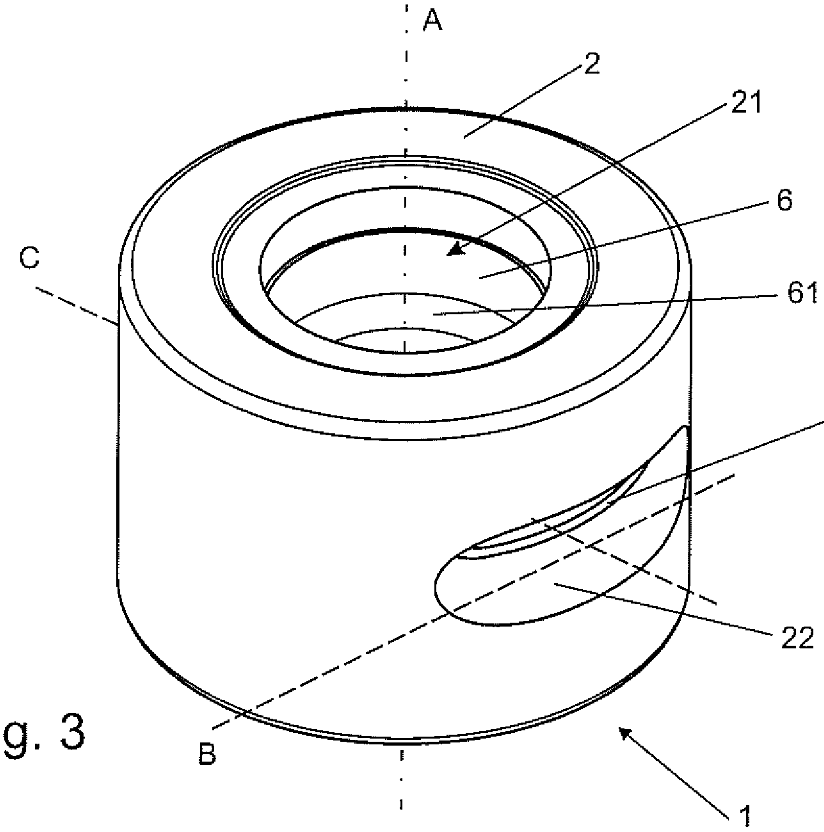


Fig. 3

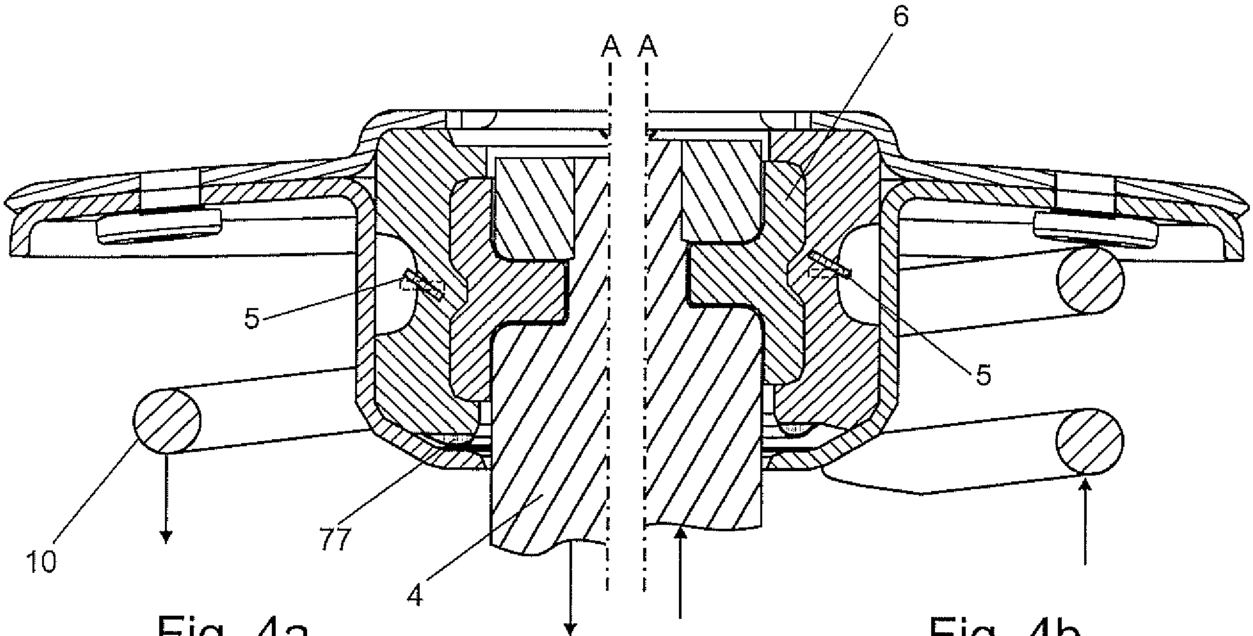
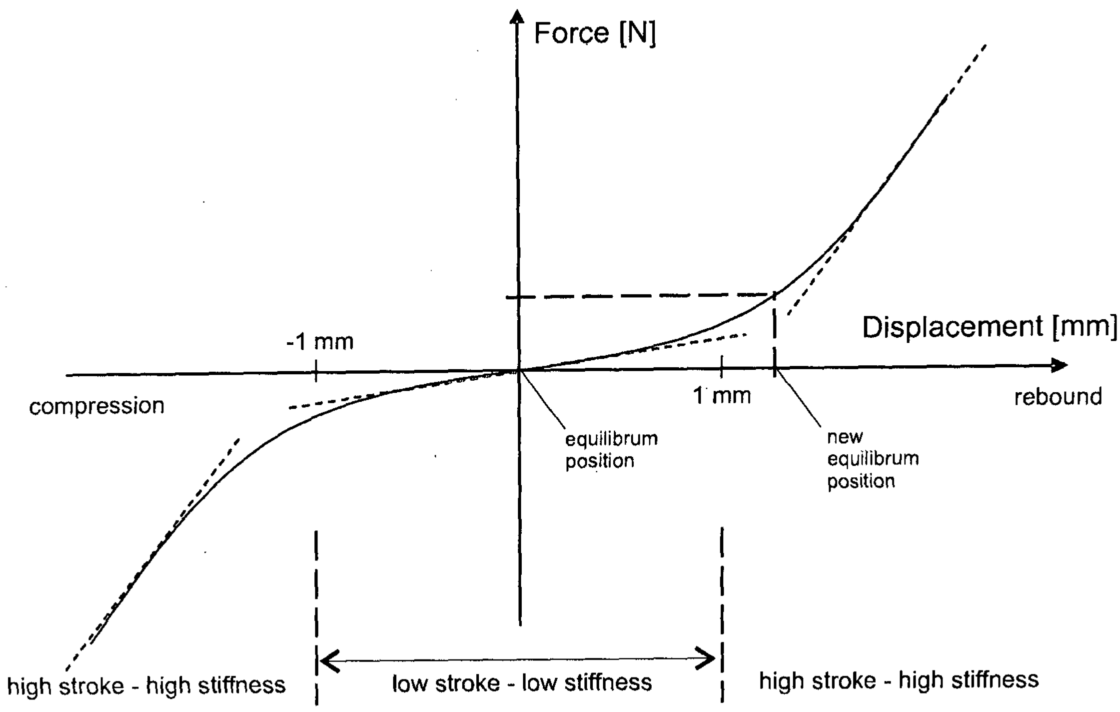


Fig. 4a

Fig. 4b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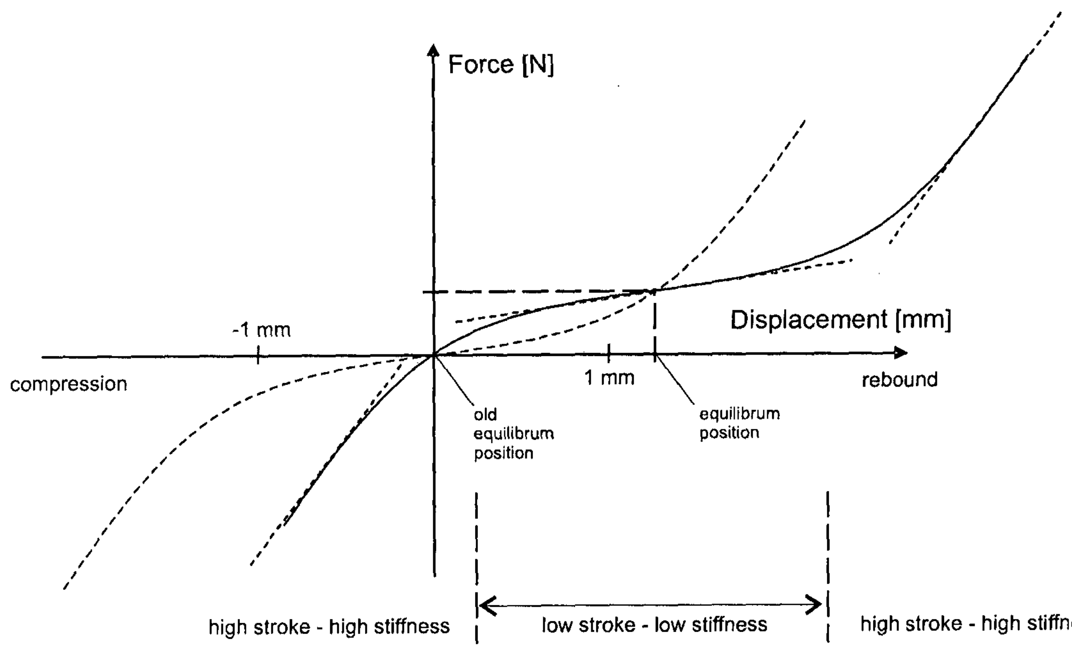
1 mm
compression
rebound
equilibrum position
new equilibrum position
high stroke - high stiffness
low stroke - low stiffness
high stroke - high stiffness

Fig. 5a


Force [N]
Displacement [mm]
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rebound
old equilibrum position
equilibrum position
high stroke - high stiffness
low stroke - low stiffness
high stroke - high stiffness

Fig. 5b

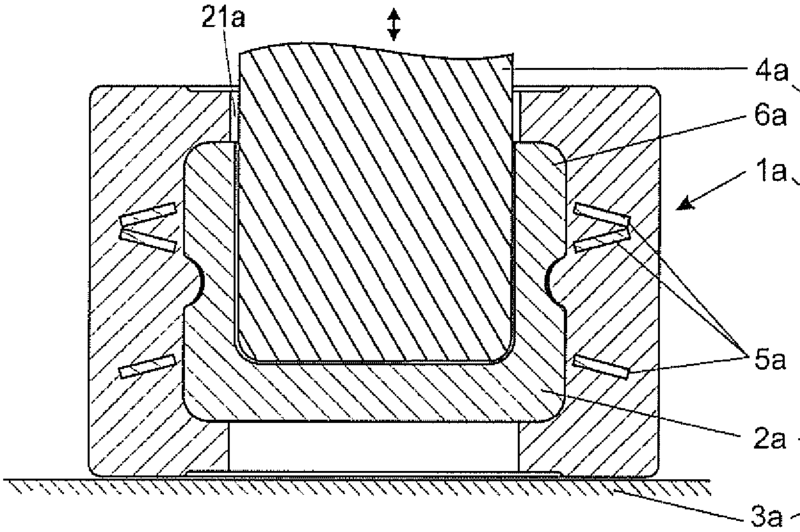

Fig. 6a

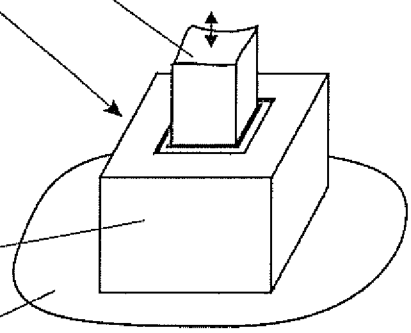

Fig. 6b

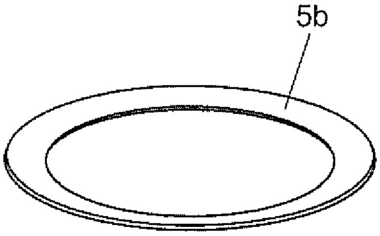

Fig. 7a

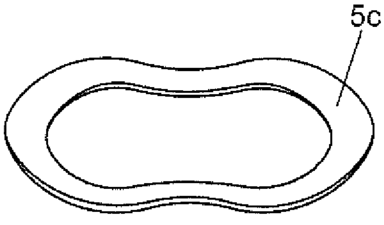

Fig. 7b

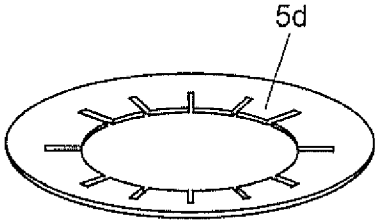

Fig. 7c

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/079150

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B60G11/-, 15/-, 13/-, 17/-, F16F9/-, 13/-, 17/-, 15/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, CNPAT: Belleville, conical, wave, spring, piston, cylinder, +load+, rebound, embed+, elastomer, elastomeric, elastic, resilient, position

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP0558115A1 (GENERAL MOTORS CORP) 01 Sep. 1993 (01.09.1993) see the whole document	1-12
A	EP0133743A2 (GENERAL MOTORS CORP) 06 Mar. 1985 (06.03.1985) see the whole document	1-12
A	US4248454A (CHRYSLER CORP) 03 Feb. 1981 (03.02.1981) see the whole document	1-12
A	US4274655A (GENERAL MOTORS CORP) 23 Jun. 1981 (23.06.1981) see the whole document	1-12
A	US4804169A(CHRYSLER CORP) 14 Feb. 1989 (14.02.1989) see the whole document	1-12

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 May.2012(11.05.2012)	**31 May 2012 (31.05.2012)**

Name and mailing address of the ISA/CN	Authorized officer
The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	XU, Zhiqing Telephone No. (86-10)62085390

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2011/079150

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
EP0558115A1	01.09.1993	US5263694A	23.11.1993
EP0133743A2	06.03.1985	US4531759A	30.07.1985
US4248454A	03.02.1981	None	
US4274655A	23.06.1981	USRE31184E	22.03.1983
US4804169A	14.02.1989	None	

Continuation of second sheet: According to International Patent Classification (IPC) or to both national classification and IPC

B60G11/42 (2006.01) i

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