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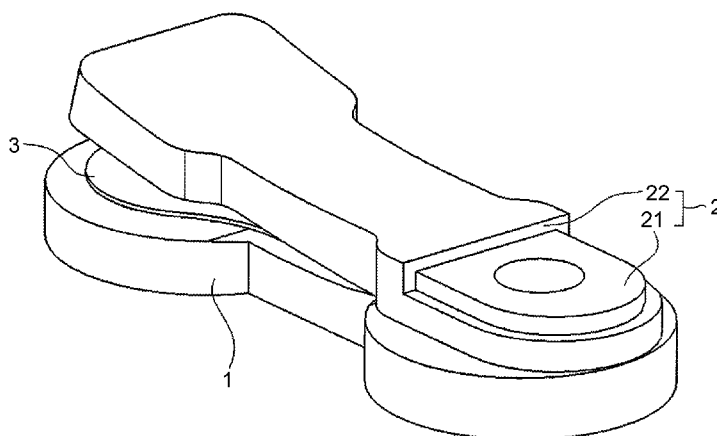
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(54) Title: POSITION-LIMITING ELEMENT, ONE-WAY VALVE, COMPOSITION, ELASTOMERIC MATERIAL, GRAFTED GRAPHITE, AND METHODS FOR PREPARING THE SAME

**Fig. 3**

(57) **Abstract:** The present invention provides a position-limiting element, a one-way valve, a composition, an elastomeric material, a grafted graphite, and methods for preparing the same, and belongs to the technical field of damping of one-way valves. The position-limiting element of the present invention used in the one-way valve is used to be provided on one end of a mobile element of the one-way valve thereby limiting the open position of the mobile element, and has an elastomeric layer made of an elastomeric material provided on one side thereof for contacting the mobile element. The one-way valve of the present invention includes the above position-limiting element, with low noise, long service life, and a high flow rate of fluid. The elastomeric material of the present invention is formed by cross-linking a composition including butyronitrile rubber; grafted graphite, including graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of a copolymer of butadiene and acrylonitrile.

**WO 2016/161252 A1**

POSITION-LIMITING ELEMENT, ONE-WAY VALVE, COMPOSITION, ELASTOMERIC MATERIAL, GRAFTED GRAPHITE, AND METHODS FOR PREPARING THE SAME

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Technical Field

The present invention belongs to the technical field of damping of one-way valves, and in particular to a position-limiting element, a one-way valve, a composition, an elastomeric material, a grafted graphite and methods for preparing the same.

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Background Art

A compressor is a core part of refrigeration equipment such as air conditioning and refrigerators, and is used in the compression of refrigerant gases. In the compressor, the one-way valve is one of the important parts, and allows the fluid to flow in only one direction, to achieve the above compression process.

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A one-way valve employed in the compressor has a structure as shown in FIGs. 1 and 2, and includes a valve body 1, a valve plate 3, and a position-limiting element 2 (a stopper).

Wherein, the valve body 1 has a valve orifice 11 provided thereon, with one end of the valve orifice 11 being opened on a surface of the valve body 1.

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The valve plate 3 may be a strip-shaped sheet made of a high cycle fatigue steel (for example, spring steel), with a fixed part on one end thereof connected onto the surface of the valve body 1, and a mobile part on the other end that can be moved back and forth between a position blocking the opening of the valve orifice 11 (a closed position) and a position going away from the surface of the valve body 1 (an open position). When the compressed fluid is to flow upwards from the inferior of the valve body 1 in FIG. 2, the fluid can push the valve plate 3 open and flow out; and when the fluid is to flow downwards from the superior of the valve body 1, fluid pressure will push the valve plate 3 in the closed position on the surface of the valve body 1, to block the valve orifice 11 and disenable the fluid to pass through, thereby achieving the function of "unidirectional flow".

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The position-limiting element 2 then includes a position-limiting part on one side where the mobile part of the valve plate 3 goes away from the valve body 1, and the remainder of position-limiting element 2 may connect to the fixed part of the valve plate 3. In a direction from the fixed part of the valve plate 3 towards the mobile part thereof, the distance between the position-limiting part and the surface of the valve body 1 increases gradually, that is, the position-limiting part of the position-limiting element 2 is gradually "tilting." An effect of the position-limiting element 2 is to "block off" the valve plate 3 when it is opening, thereby limiting the maximum distance of the valve plate 3 away from the valve body 1, i.e., limiting the open position of the valve plate 3, so as to avoid the damage due to undue deformation of the valve plate 3, and to ensure that the valve plate 3 can rapidly return to the closed position to improve efficiency.

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At present, the working frequency of a compressor of the refrigeration equipment is usually between 20 Hz and 100 Hz, which means that the valve plate therein is switched at least 20 times per second, and the valve plate will strike the position-limiting element in each switch. The impact, on the one hand, will cause greater noise (in fact, the noise is the greatest source of noise in the compressor), and on the other hand, will generate greater stress on the valve plate when the impact is happening, thereby reducing the service life thereof. At the same time, in order to avoid damage to the valve plate, a maximum distance between the position-limiting element and the valve body surface should not be too long, i.e., a maximum opening degree of the valve plate (also referred to as an "opening degree" or "lift range" of the valve plate) should not be too high, which will otherwise influence the flow rate of a refrigerant and reduce energy efficiency of the compressor.

Summary of the Invention

One objective of the present invention is to provide a position-limiting element for use in one-way valves. The position-limiting element can effectively cushion the impact suffered by a mobile element (for example, a valve plate), thereby to reduce noise, prolong service life of the mobile element, increase the opening degree of the mobile element, increase the flow rate of fluid through the one-way valve, and ameliorate energy efficiency of the compressor.

The position-limiting element for use in a one-way valve is used to be provided on one end of a mobile element of the one-way valve, thereby to limit the open position of the mobile element, wherein, the position-limiting element has an elastomeric layer made of an elastomeric material provided on one side thereof used for contacting the mobile element.

Wherein, preferably, the above elastomeric material is preferably formed by cross-linking a composition including butyronitrile rubber (preferably, hydrogenated butyronitrile rubber); grafted graphite, including graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of a copolymer of butadiene and acrylonitrile.

Wherein, preferably, the one-way valve is preferably a one-way valve used in a compressor.

Another objective of the present invention is to provide a position-limiting element for use in a one-way valve of a compressor, which is used to be provided on one end of a valve plate of the one-way valve of the compressor, thereby to limit the open position of the valve plate, wherein,

the position-limiting element has an elastomeric layer made of an elastomeric material provided on one side thereof used for contacting the mobile element, and the elastomeric material is formed by cross-linking a composition including:

butyronitrile rubber;

grafted graphite, including graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of a copolymer of butadiene and acrylonitrile;

and

the butyronitrile rubber in the composition has a content by weight percentage of 28% to 60%;

the grafted graphite in the composition has a content by weight percentage of 2% to 12%; and

in the grafted graphite, the graft groups have a proportion by weight of 6% to 20%, with respect to the weight of the graphite particles.

Wherein, preferably, the elastomeric layer has a thickness from 0.1 mm to 5 mm;

the valve plate includes a fixed part for connecting on the valve body of the one-way valve, and a
5 mobile part for movement with respect to the valve body;

the position-limiting element includes a position-limiting part for limiting the open position of the valve plate, and a surface of the position-limiting part on one side for facing towards the valve plate is a cambered convex surface; and when the position-limiting element is provided in the one-way valve, in a direction from the fixed part of the valve plate towards the mobile part thereof, the cambered convex surface
10 has a curvature from $1/72 \text{ mm}^{-1}$ to $1/172 \text{ mm}^{-1}$.

A further objective of the present invention is to provide a one-way valve using the above position-limiting element. The one-way valve includes:

a valve body having a valve orifice;

a mobile element provided on one end of the valve body, for movement between a closed position
15 sealing the valve orifice and an open position going away from the valve orifice; and

the above position-limiting element provided on one end of the mobile element, for limiting the open position of the mobile element, and having an elastomeric layer made of an elastomeric material provided on one side thereof for contacting the mobile element.

Wherein, the one-way valve is preferably a one-way valve used in a compressor.

Wherein, the above elastomeric material is preferably formed by cross-linking a composition including
20 butyronitrile rubber (preferably, hydrogenated butyronitrile rubber); grafted graphite, including graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of a copolymer of butadiene and acrylonitrile.

Another objective of the present invention is to provide a grafted graphite, which is one of raw
25 materials for use in the preparation of the above elastomeric material.

The grafted graphite includes graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of the copolymer of butadiene and acrylonitrile.

A further objective of the present invention is to provide a method for preparing the above grafted graphite, including:

30 functionalizing the graphite particles; and

grafting the graft groups onto the graphite particles, to obtain grafted graphite, wherein the graft groups include groups of the copolymer of butadiene and acrylonitrile.

A further objective of the present invention is to provide a composition that can be used to form the above elastomeric material, including:

35 butyronitrile rubber (preferably hydrogenated butyronitrile rubber); and

the above grafted graphite, including graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of the copolymer of butadiene and acrylonitrile.

An additional objective of the present invention is to provide an elastomeric material, which has, in addition to good mechanical performance, very good resistance to oil and refrigerant (aging resistance) and good dynamic aging resistance, and thus is particularly suitable for use as an elastomeric layer in a one-way valve of a compressor.

5 The elastomeric material is formed by cross linking from the above composition including:
butyronitrile rubber (preferably hydrogenated butyronitrile rubber); and
grafted graphite, including graphite particles and graft groups grafted on the graphite particles,
wherein the graft groups include groups of the copolymer of butadiene and acrylonitrile.

10 Description of the Drawings

FIG. 1 is a structural representation of a one-way valve of an existing compressor;

FIG. 2 is a structural representation of a cross section of a one-way valve of an existing compressor;

FIG. 3 is a structural representation of a one-way valve of a compressor according to an example of the present invention;

15 FIG. 4 is a structural representation of a cross section of a one-way valve of a compressor according to an example of the present invention;

FIG. 5 is a photograph of an elastomeric layer in a one-way valve of a compressor according to an example of the present invention;

20 FIG. 6 is a structural representation of a cross section of a one-way valve of another compressor according to an example of the present invention;

FIG. 7 is a structural representation of a cross section of a one-way valve of another compressor according to an example of the present invention;

FIG. 8 is a transmission electron microscope (TEM) photograph of graphite particles in a composition according to an example of the present invention;

25 FIG. 9 is a mimic distribution diagram of the maximum stress suffered by each part of a valve plate of an existing one-way valve in one motion cycle;

FIG. 10 is a mimic distribution diagram of the maximum stress suffered by each part of a valve plate of a one-way valve according an example of the present invention in one motion cycle;

30 FIG. 11 is a mimic diagram of vibration situation of a valve plate of an existing one-way valve in one motion cycle;

FIG. 12 is a mimic diagram of vibration situations of a valve plate of a one-way valve according an example of the present invention in one motion cycle;

FIG. 13 is a photograph of surface topography of an existing butyronitrile rubber after an aging resistance test;

35 FIG. 14 is a photograph of surface topography of an existing hydrogenated butyronitrile rubber after an aging resistance test;

FIG. 15 is a photograph of surface topography of an elastomeric material according to an example of the present invention after an aging resistance test;

FIG. 16 is a comparative photograph of sizes of an existing butyronitrile rubber before and after an aging resistance test; and

FIG. 17 is a comparative photograph of sizes of an elastomeric material according to an example of the present invention before and after an aging resistance test;

wherein, reference numbers of the accompanying drawings are: 1. valve body; 11. valve orifice; 2. position-limiting element; 21. basal body; 22. elastomeric layer; 23. rigid layer; 3. valve plate; 91. first stage; 92. second stage; H. maximum distance; α . included angle.

Detailed Description of the Preferred Embodiments

In order to allow those of skill in the art to better comprehend technical solutions of the present invention, the present invention will be further described in detail below in conjunction with accompanying drawings and particular embodiments.

Interpretation of terms

In the present invention, the following terms or description manners have meanings as follows.

The description of "A and/or B" denotes that either of the situations, wherein either or both of which are present, may be occurred, i.e., the description includes three situations, "A and B", "A", and "B".

The description of "A to B" includes a value of A, a value of B, and any value greater than A and less than B. For example, "1 to 10" includes 1, 10 and any value greater than 1 and less than 10, e.g., 2, 3, 4, 5, 6, 7, 8, 9, 2.358, 3.5, 5.26, 7.18, 9.999, and the like.

The description of "about A" or "essentially A" denotes that the target is A, but there are inevitable and allowable errors that may be present between an actual value and A under a prior art condition.

By "molecular weight", molecular weights referred herein are all weight average molecular weights, and are all obtained by the gel gas chromatography method (GPC), unless otherwise stated.

By "an amount of a substance used", amounts or ratios of the amounts of substances used herein all refer to weights or ratios by weight, unless otherwise stated.

"A content by weight percentage of A in B" means that A belongs to a part of B, and refers to the percentage of the weight of A, when the weight of B (including A) is 100%.

"A proportion by weight of A with respect to the weight of B" means that A is not a part of B, and refers to the percentage by weight of A with respect to the weight of B, when the weight of B is 100%.

A "compressor" refers to a mechanism for use in the compression of a refrigerant in refrigeration equipment (for example, refrigerators and air conditioning).

A "one-way valve" refers to a valve, which allows a fluid to flow from one side to the other side thereof, instead of allowing the fluid to flow in a reverse direction.

An "elastomeric material" refers to a material (usually a polymer) that can have greater elastic deformation, and "elastic deformation" refers to deformation that can dissipate completely or virtually after removal of stress causing the strain.

A "rigid material" refers to a material with greater hardness and rigidity, so that it fails to have elastic deformation or has only tiny elastic deformation.

"Peel stress along a 180° direction" refers to, for two mutually binding structures, the stress required for peeling the two from each other in a direction at an angle of 180° with respect to a binding surface thereof, and has a unit of "Newton/millimeter."

Position-limiting element and one-way valve

An example of the present invention provides a position-limiting element for use in a one-way valve, and a one-way valve using the position-limiting element.

Because the one-way valve includes the position-limiting element, the one-way valve is introduced directly herein, then at the same time the position-limiting element therein is also illustrated.

In particular, the one-way valve includes:

a valve body having a valve orifice;

a mobile element provided on one end of the valve body, for movement between a closed position sealing the valve orifice and an open position going away from the valve orifice; and

a position-limiting element provided on one end of the mobile element, for limiting the open position of the mobile element, and having an elastomeric layer made of an elastomeric material provided on one side thereof for contacting the mobile element.

In the one-way valve according to an example of the present invention, there is an elastomeric layer at a position where the mobile element (for example, a valve plate) contacts the position-limiting element, so that when the mobile element impacts upon the position-limiting element, the elastomeric layer can deform and generate a cushioning effect, to prolong stress time of the mobile element, reduce impact strength suffered, avoid stress concentration and vibration, and therefore to reduce noise, prolong service life of the mobile element, and to allow the mobile element to have a higher opening degree to increase the flow rate of fluid through the one-way valve.

Of course, it is to be understood that, the above one-way valve (including the position-limiting element) may be produced and sold as a product. However, the position-limiting element may also be produced and sold as an independent product, so long as it is installed on a one-way valve (for example, a one-way valve of a compressor) later.

Preferably, the elastomeric material has an extension at break of at least 10%; more preferably, it has a stress of at least 0.5 MPa when the stretching strain is 10%.

Apparently, the elasticity performance of an elastomeric material has a considerable influence on the cushioning effect thereof. Studies have found that elastomeric materials in compliance with the above condition can satisfy the cushioning requirement better.

Preferably, the elastomeric material has a Shore A hardness from 30 to 80, and further preferably from 30 to 70, at 23 degrees Celsius.

Because the elastomeric layer frequently suffers from impact by the mobile element, there are certain requirements for the hardness thereof. An elastomeric layer that is too soft is susceptible to abrasion itself,

and an elastomeric layer that is too hard fails to exert a good cushioning effect. It is found via studies that the above hardness range is relatively appropriate.

Preferably, the elastomeric material is a damping rubber.

That is to say, the above elastomeric material may also be a damping material (for example, a damping rubber), thereby exerting cushioning and damping effects better. In particular, damping rubbers that may be used are preferably damping rubbers from the 3M Corporation, e.g., damping rubbers of the types such as VC308 and VC310 from the 3M Corporation.

Preferably, the elastomeric material may also be other conventional polymeric materials, and may, in particular, include any one or more of the following types: polyamide, for example Nylon 66, and semi-aromatic nylon; polyurethane, for example polyester-type polyurethane, hot melt-type polyurethane, and polyurethane composite materials; polyolefine and polyolefine derivatives, for example polypropylene, polyethylene, natural rubber, butadiene rubber, butyronitrile rubber (preferably hydrogenated butyronitrile rubber), etc.; thermoplastic vulcanized rubber; fluororubbers, for example perfluoroether rubbers, fluorosilicone rubbers, fluoroether rubber, etc.; acrylic rubbers, for example ethylene acrylate rubber, epoxy-type acrylic rubber, etc.; epoxy resins, for example solid epoxy resin, liquid curable epoxy resin, etc.; and phenol formaldehyde resins.

Of course, elastomeric materials that may be used are not limited to the above examples, and other known elastomeric materials may also be selected as the elastomeric layer by those skilled in the art.

As a preferred embodiment of an example of the present invention, the elastomeric material of the above elastomeric layer may be formed by cross-linking a composition, including:

butyronitrile rubber (preferably hydrogenated butyronitrile rubber); and

grafted graphite, including graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of a copolymer of butadiene and acrylonitrile.

Preferably, the butyronitrile rubber in the composition has a content by weight percentage from 28% to 60%; and the grafted graphite in the composition has a content by weight percentage from 2% to 12%.

Preferably, in the grafted graphite, the graft groups have a proportion by weight from 6% to 20%, with respect to the weight of the graphite particles.

The one-way valve of the present invention is preferably a one-way valve in a compressor of refrigeration equipment. This one-way valve has a work environment filled up with oil (for example, a lubricating oil) and a refrigerant, and has higher working temperature and pressure. Therefore, the material of the elastomeric layer should preferably have better resistance to the oil and refrigerant (aging resistance), to ensure that the elastomeric layer has unchanged physical properties (for example, hardness and mechanical performance) and size in the course of use. At the same time, the elastomeric layer will suffer repeatedly from impact by the valve plate and tiny deformation in use, dynamic aging resistance, abrasion resistance and the like thereof are also important.

In the above elastomeric material, grafted graphite is distributed in a base material based on the butyronitrile rubber (preferably hydrogenated butyronitrile rubber). The grafted graphite has similar graft groups to the butyronitrile rubber molecules, on the graphite particles, and thus can be co-crosslinked with the butyronitrile rubber base material to eliminate the interface between the graphite particles and the

butyronitrile rubber, thereby blending well into the base material, and therefore the presence of grafted graphite will not cause adverse effects to mechanical performances such as strength of the butyronitrile rubber. At the same time, as a result of intrinsic properties of graphite, particles thereof are necessarily in a flaky shape, and therefore graphite particles in the flaky shape can block incursion of refrigerant, oil and the like, thereby increasing aging resistance of the elastomeric material; and graphite in the flaky shape can further have effects of ameliorating abrasion resistance and dynamic aging resistance of the elastomeric material, and increasing the capacity thereof of resisting valve plate impact. That is to say, the above composition has, in addition to good mechanical performance, quite outstanding aging resistance, dynamic aging resistance, abrasive resistance and the like, and thus is particularly suitable for use as an elastomeric layer of a one-way valve of a compressor. Specific circumstances of the elastomeric material will be further introduced in detail in a section after this patent, and unnecessary details are not given herein.

Preferably, as shown in FIGs. 3, 4, 6, and 7, a position-limiting element 2 includes a basal body 21; and an elastomeric layer 22 is provided at least on one side for contacting a mobile element (for example, a valve plate 3), of a basal body 21.

That is to say, the position-limiting element 2 may include a conventional basal body 21 made of a hard material (for example, steel), which defines a basic shape and a main part of the position-limiting element 2. An elastomeric layer 22 is provided on one side for contacting the mobile element, of the basal body 21. Of course, other parts of the basal body 21 may also be provided with the elastomeric layer 22.

In particular, as a preferred embodiment of an example of the present invention, as shown in FIG. 3, 4, and 6, the elastomeric layer 22 is located on the outermost side of the position-limiting element 2.

That is to say, one elastomeric layer 22 may be provided directly and exclusively on a surface on one side for contacting the mobile element, of the basal body 21.

Preferably, as an embodiment of an example of the present invention, the elastomeric layer 22 is sleeved on the basal body 21, and the force required to pull the elastomeric layer 22 away from the basal body 21 is at least 30 N.

That is to say, the elastomeric layer 22 may, as shown in FIG. 5, form a separate "sleeve-shaped" device, with a structure that can be connected to the basal body 21. Accordingly, as shown in FIGs. 3 and 4, the elastomeric layer 22 may be engaged or sleeved onto the basal body 21 in a mechanical manner. When this embodiment is employed, if the elastomeric layer 22 is to be pulled down from the basal body 21, a force of at least 30 N is required. Such an embodiment relatively facilitates the replacement of the elastomeric layer 22.

Preferably, as another embodiment of an example of the present invention, as shown in FIG. 6, the elastomeric layer 22 is bonded on the basal body 21, and a peel stress along a 180° direction between the elastomeric layer 22 and the basal body 21 is at least 0.6 Newton/millimeter.

That is to say, the elastomeric layer 22 may also be connected onto the basal body 21 in a binding manner. For example, a binder of epoxies, acrylics, polyurethanes and the like may be coated onto the basal body 21 to then bind the elastomeric layer 22 thereon. Alternatively, the elastomeric layer 22 may also be connected onto the basal body 21 by coating a rubber-type binder on the basal body 21, followed by heating

to allow the elastomeric layer 22 to co-crosslink (covulcanize) with the basal body 21. Also, in such a case, the 180° peel stress between the elastomeric layer 22 and the basal body 21 is at least 0.6 Newton/millimeter.

As another preferred embodiment of an example of the present invention, as shown in FIG. 7, a rigid layer 23 is provided on one side for contacting the mobile element, of the elastomeric layer 22.

That is to say, not only the elastomeric layer 22 may be provided on the basal body 21, but also a rigid layer 23 made of a rigid material may be further provided outside the elastomeric layer 22.

That is to say, a layer on the outermost side of the position-limiting element is made of the rigid material, and the elastomeric layer 22 is encased in the rigid layer 23. In particular, the rigid material may be steel, cast iron, copper alloys, aluminium, aluminium alloys, titanium alloys, lead, ceramic materials and the like. This design has advantages in that: the layer located on the outermost side suffers directly from impacts by the mobile element (for example, the valve plate 3), and has direct contact with the external environment (for example, refrigerant and oil), thus it needs higher abrasive resistance, corrosion resistance and the like. Traditional rigid materials have better performance in this respect, and the use thereof in the outermost side may fully exert advantages thereof. At the same time, the elastomeric layer 22 is further provided in the rigid layer 23, and thus impacts by the mobile element may be conducted onto the elastomeric layer 22 through the rigid layer 23, and the elastomeric layer 22 is still able to exert a cushioning effect.

Preferably, the rigid layer 23 is bonded on the elastomeric layer 22, and the peel stress along the 180° direction between the elastomeric layer 22 and the rigid layer 23 is at least 0.6 Newton/millimeter.

Apparently, the rigid layer 23 is insusceptible to deformation, and is inconvenient to be connected onto the flexible elastomeric layer 22 in mechanical manners such as engaging or sleeving, therefore it is bonded to the elastomeric layer 22 preferably employing a manner of binding connection.

Of course, a "stack structure" (wherein an elastomeric layer 22 must be included) composed of layers of a plurality of different materials may also be provided on the basal body 21. The total number of the layers in the stack structure is preferably between 2 and 20. Also, particular arrangement forms of the layers in the stack structure is diversified. For example, multiple sets of the rigid layer 23 and the elastomeric layer 22 arranged alternately may be included, or a plurality of continuous rigid layers 23 or a plurality of continuous elastomeric layers 22 and the like may be included.

Preferably, in the above one-way valve, a thickness of the basal body 21 may be between 0.5 mm and 4 mm; a thickness of the elastomeric layer 22 is from 0.1 mm to 5 mm, more preferably from 0.5 mm to 1.5 mm; and a thickness of the rigid layer 23 is preferably between 0.01 mm and 4 mm.

Apparently, for the above elastomeric layer 22, the rigid layer 23 and the like, if the thickness thereof is too low, respective effects cannot be exerted, and if the thickness is too high, other performance may be influenced (for example, if the rigid layer 23 is too thick, the elastomeric layer 22 will fail to exert the cushioning effect).

Preferably, the one-way valve according to an example of the present invention is a one-way valve used in a compressor, and the above position-limiting element is a position-limiting element used in a one-way valve of

a compressor. More preferably, as shown in FIGs. 3, 4, 6, and 7, in the one-way valve (a one-way valve of a compressor):

the valve body 1 includes a first surface, with an opening of a valve orifice 11 on the first surface;

the mobile element is a valve plate 3 including a fixed part and a mobile part, wherein the fixed part is connected onto the first surface, and the mobile part is used to move between the closed position covering the valve orifice 11 and the open position going away from valve orifice 11 (i.e., to move with respect to the valve body 1); and

the position-limiting element 2 includes a position-limiting part located on one side where the valve plate 3 goes away from the first surface, and in a direction from the fixed part of the valve plate 3 towards the mobile part thereof, the distance between the position-limiting part and the first surface increases gradually.

That is to say, for the one-way valve in the compressor, the mobile element is preferably in a form of the valve plate 3, which is a strip-shaped sheet, and may be made of a high cycle fatigue steel (for example, a spring steel), with one end (the fixed part) connected onto the valve body 1, and the other end (the mobile part) that is flexible and deformable, thereby to be able to move back and forth between the closed position where it attaches to the surface of the valve body 1 and the open position where it goes away from the surface of the valve body 1.

Whereas the position-limiting element 2 may also be fixedly connected, on one end, to the surface of the valve body 1, and includes a position-limiting part located above the mobile part of the valve plate 3, thereby limiting the distance the valve plate 3 goes away from the surface of the valve body 1 (i.e., the open position). At the same time, the position-limiting part of the position-limiting element 2 is provided obliquely, with its "root" being the closest to the surface of the valve body 1, and its "front end" being the farthest from the surface of the valve body 1, so that the position-limiting part is a structure "tilting" from the root towards the front end, such that the opening degree of the valve plate 3 can be limited to a gradually increasing form.

Preferably, for the above one-way valve for use in a compressor, a surface on the side of the position-limiting part 2 facing towards the valve plate 3 is a cambered convex surface.

That is to say, as shown in FIGs. 4, 6, and 7, a surface for contacting the valve plate 3, of the position-limiting part of the position-limiting element 2, is preferably a cambered surface instead of a plane, and the cambered surface is a cambered convex surface projecting towards the valve plate 3. That is to say, in a direction from the fixed part of the valve plate 3 towards the mobile part, the cambered convex surface has an increasingly greater tilting degree with respect to the first surface. This design of the cambered convex surface can allow the stress, as the valve plate 3 is opening, to be dispersed. At the same time, as shown in FIG. 4, under the circumstance in compliance with the above condition, the process in which the valve plate 3 is opened and has contact with the position-limiting element 2 may be carried out in two stages as follows. When the valve plate 3 impacts on the position-limiting element 2, it is bent first and attached onto a surface of the position-limiting element 2 (i.e., a first stage 91), and then the elastomeric layer 22 of a projecting portion is subjected to compressive deformation due to the stress, changes are generated in the surface shape of the position-limiting element 2, and the valve plate 3 also further moves upwards into a position of a

dotted second stage 92 in the figure. That is to say, the impact process of the valve plate 3 becomes "staged", thereby allowing the stress on the valve plate to be dispersed uniformly, and eliminating the stress concentration region.

As shown in FIG. 6, more preferably, in a direction from the fixed part of the valve plate 3 towards the mobile part thereof, the cambered convex surface of the position-limiting element 2 has a curvature preferably from $1/72 \text{ mm}^{-1}$ to $1/172 \text{ mm}^{-1}$; and/or, an angle α between a tangent plane of the above cambered convex surface in a position that is the closest to the first surface and the first surface is from 9° to 40° (in the figure, the valve plate 3 is parallel with the first surface, so that one end of the α angle is drawn on the surface of the valve plate 3). Preferably, the maximum distance H between one side of the position-limiting part of the position-limiting element 2 that is close to the first surface and the first surface is from 3 mm to 32 mm.

That is to say, the above cambered convex surface has a curvature preferably between $1/72 \text{ (mm}^{-1}\text{)}$ and $1/172 \text{ (mm}^{-1}\text{)}$, such that the above "staged" impact process can be ensured better. At the same time, the angle α between the root of the position-limiting part of the position-limiting element 2 and the surface of the valve body 1 is preferably from 9° to 40° . Also, the distance H between the front end of the position-limiting part of the position-limiting element 2 and the surface of the valve body 1 is preferably between 3 mm and 32 mm. In particular, for a one-way valve in a refrigerator compressor, the distance H may be from 3 mm to 18 mm, and for a one-way valve of an air conditioning compressor, the distance H may be from 5 mm to 32 mm.

It is obvious that, the above maximum distance H, curvature, and angle α together limit the maximum opening degree (opening degree) of the valve plate 3, and the greater they are, the greater the maximum opening degree of the valve plate 3 is, the greater the flow rate of fluid through the one-way valve is, and the higher the energy efficiency of the compressor is; but correspondingly, the greater the deformation of the valve plate 3 is, and the higher susceptibility to damage it has. Because the position-limiting element 2 of the one-way valve according to an example of the present invention includes the elastomeric layer 22, which can effectively reduce stress concentration on the valve plate 3, each of the above parameters has a greater value range than that in the prior art, i.e., the example of the present invention can increase the maximum opening degree of the valve plate 3 without damaging the valve plate 3, thereby improving the flow rate of fluid through the one-way valve and energy efficiency of the compressor.

What is introduced above is a structure of a one-way valve in a compressor. However, it is obvious that, use of the one-way valve according to examples of the present invention is not limited to a compressor, and the one-way valve may also be a one-way valve used in an automobile valve. Also, the structure of the one-way valve according to examples of the present invention is not limited to the above concrete form either. For example, the mobile part thereof may also be a "plunger" that can move between a position blocking the valve orifice (closed position) and a position going away from the valve orifice (open position). In summary, any one-way valve having a valve body, a mobile element, and a position-limiting element including the above elastomeric layer belongs to the protection scope of the present invention.

Grafted graphite

1. Grafted graphite

An example of the present invention further provides a grafted graphite, which can be used in the above composition that can be used to form the elastomeric material of the elastomeric layer of the above compressor one-way valve.

In particular, the grafted graphite includes graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of a copolymer of butadiene and acrylonitrile.

Wherein, the "copolymer of butadiene and acrylonitrile" is a butyronitrile rubber. That is to say, in the grafted graphite of an example of the present invention, basic groups of butyronitrile rubber molecules are grafted on the graphite particles.

Wherein, the above graphite particles have a particle size preferably between 200 nm and 5000 nm.

The graphite particles within the particle size range may be uniformly dispersed in the base material (butyronitrile rubber), and plays a role in the amelioration of performance (for example, aging resistance) of the elastomeric layer.

Preferably, in the grafted graphite, the graft groups have a proportion by weight between 6% and 20%, and more preferably between 6% and 17%, with respect to the weight of the graphite particles.

That is to say, in the grafted graphite, a ratio by weight of simple graft groups to simple graphite particles is preferably from (0.06 to 0.2): 1, or alternatively, an "graft amount" on the graphite particles is between 0.06 and 0.2. It is obvious that, the amount of the graft groups on the graphite particles has an important impact on the performance of the elastomeric material. It has been found via studies that, the graft amount within the above proportion range can ameliorate aging resistance of the elastomeric material the most effectively. A graft amount too low leads to inconspicuous effects, and a graft amount too high leads to difficulty in realization of the grafting process.

Preferably, the above graft groups are groups of the hydrogenated copolymer of butadiene and acrylonitrile, and preferably groups of the terminated (for example, amino-terminated) copolymer of butadiene and acrylonitrile.

That is to say, the butyronitrile rubber (a copolymer of butadiene and acrylonitrile) for use in grafting the graphite particles is preferably hydrogenated butyronitrile rubber and terminated butyronitrile rubber, such that aging resistance of the elastomeric material can be ameliorated better.

2. Method for preparing grafted graphite

An example of the present invention further provides a method for preparing the above grafted graphite, including:

functionalizing the graphite particles; and

grafting the graft groups onto the graphite particles, to obtain grafted graphite, wherein the graft groups include groups of a copolymer of butadiene and acrylonitrile.

That is to say, the graphite particles in a flaky shape may be functionalized first, to connect with desired functional groups, and then the above graft groups are grafted onto the graphite particles by these functional groups.

In particular, the method for preparing the grafted graphite may include the following steps:

5 S101: the graphite particles are mixed with a strong oxidizer.

Wherein, benzoyl peroxide (BPO) is selected as the strong oxidizer, and thus this step in particular includes: mixing a raw material graphite with benzoyl peroxide according to a ratio by weight of 100: 6, grinding and mixing the mixture for 2 h under a condition of a ratio of grinding media to the material at 3 to 4, through a ball milling method, to reduce the particle size of the raw material graphite to the above particle size range of graphite particles, and intensively mixing with benzoyl peroxide.

FIG. 8 is a scanning electron photomicrograph of graphite particles, and it can be seen that, the graphite particles are in an evident flaky shape, with a particle size thereof in the above range from 200 nm to 5000 nm.

S102: heating is carried out, to allow the graphite particles to be functionalized.

15 This step in particular includes heating a mixture of the graphite particles and the strong oxidizer to 110°C and maintaining for 10 min.

In order for the comparability of results, in examples of the present invention, the above benzoyl peroxide is employed as the strong oxidizer, and the above heating parameters are employed uniformly. However, it is obvious that, other substances may be used as the strong oxidizer.

20 For example, dicumyl peroxide may also be used as the strong oxidizer, in which case, a ratio by weight of the raw material graphite to dicumyl peroxide does not exceed 3: 1 maximally, and the heating may be maintained for 1 h at a temperature of 150°C.

For example again, potassium permanganate may also be used as the strong oxidizer, in which case, a ratio by weight of the raw material graphite to potassium permanganate does not exceed 3: 1 maximally, and the heating may be maintained for 2 h at a temperature of 160°C.

25 S103: the graphite particles are cooled to room temperature, then elutriated sufficiently, and then oven dried, so as to obtain a tan powder, that is functionalized graphite particles.

At this time, a substantial amount of functional groups are grafted onto the graphite particles in a flaky shape, wherein functional groups connected to the peripheral part of the graphite particles in a flaky shape are based on carboxyl and hydroxy groups, and functional groups connected to the middle part are based on epoxy groups.

30 S104: the graphite particle are added into N,N-dimethyl formamide (DMF), and subjected to ultrasonic processing for 15 min, so as to obtain a homogeneous suspension.

Wherein, N,N-dimethyl formamide has a proportion by weight preferably from 350% to 450% with respect to the weight of the graphite particles, i.e., a ratio by weight of the graphite particles to N,N-dimethyl formamide is from 1: (3.5 to 4.5).

35 S105: the copolymer of butadiene and acrylonitrile (i.e., butyronitrile rubber, but this butyronitrile rubber is a raw material for preparing grafted graphite, and is different from the butyronitrile rubber in a composition

product) and dicyclohexylcarbodiimide (DCC) are added into the above suspension, and stirred for 30 min to allow uniform distribution.

Wherein, dicyclohexyl carbodiimide has a proportion by weight preferably from 1% to 5% with respect to the weight of the graphite particles, i.e., a ratio by weight of the graphite particles to dicyclohexyl carbodiimide is from 1: (0.01 to 0.05).

Wherein, the copolymer of butadiene and acrylonitrile has a proportion by weight preferably from 18% to 40% with respect to the weight of the graphite particles, i.e., a ratio by weight of the graphite particles to the copolymer of butadiene and acrylonitrile is from 1: (0.18 to 0.4).

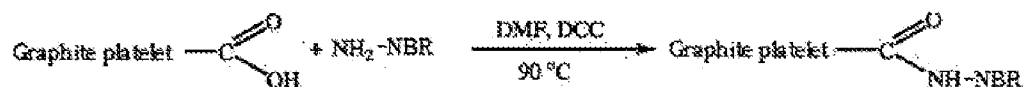
In general, during a reaction process, the copolymers of butadiene and acrylonitrile are unlikely to graft wholly onto the graphite particles, so that the amount of the copolymer of butadiene and acrylonitrile used in the reactants must be greater than the amount of graft groups desired in a product of the grafted graphite. Studies find that, according to the above amount used, it can be ensured that the graft amount in the product of the grafted graphite is in compliance with the above range from 0.06 to 0.2.

Wherein, the copolymer of butadiene and acrylonitrile is preferably a terminated (for example, amino-terminated) liquid-state butadiene - acrylonitrile copolymer, and the copolymer of butadiene and acrylonitrile is preferably a hydrogenated butadiene - acrylonitrile copolymer undergone hydrogenation treatment. In order for the comparability of results, in all examples of the present invention, amino-terminated liquid-state butyronitrile rubber is used as the raw material.

S106: the suspension is heated to allow graft groups to graft onto the graphite particles.

Wherein, the heating is preferably carried out for 20 h to 28 h at a temperature of 80°C to 100°C with heat preservation. In order for the comparability of results, in examples of the present invention, the heating is carried out for 24 h at a temperature of 90°C uniformly.

In the heating process, a process of the grafting reaction is as follows:



Wherein, graphite platelet denotes flaky graphite particles, NBR denotes groups of a copolymer of butadiene and acrylonitrile, and NH₂-NBR denotes an amino-terminated butyronitrile rubber raw material.

S107: the suspension is filtered, and the filtration product is oven dried to obtain a powder, that is the above grafted graphite.

Composition

An example of the present invention further provides a composition, including:

butyronitrile rubber; and

grafted graphite, including graphite particles and graft groups grafted on the graphite particles, wherein the graft groups include groups of the copolymer of butadiene and acrylonitrile.

The composition according to an example of the present invention includes butyronitrile rubber (a separate butyronitrile rubber, instead of the groups grafted on the graphite particles) and the above grafted graphite, which can obtain the above elastomeric material of the elastomeric layer by cross-linking.

Preferably, in the composition, the butyronitrile rubber has a content by weight percentage from 28% to 60%; the grafted graphite has a content by weight percentage from 2% to 12%; furthermore preferably, the butyronitrile rubber has a content by weight percentage from 30% to 50%; the grafted graphite has a content by weight percentage from 3.5% to 7.5%.

5 The butyronitrile rubber and the above grafted graphite are the most important components in the composition, their contents have important influences on performance of the elastomeric materials formed therefrom, and it is found via studies that the above content ranges are preferred.

Preferably, the butyronitrile rubber herein is hydrogenated butyronitrile rubber.

That is to say, the butyronitrile rubber as a main base material of the composition is also hydrogenated,
10 to further ameliorate the aging resistance of the elastomeric material of the product. For example, the butyronitrile rubber that may be used herein includes commercially available butyronitrile rubber products under trademarks 3406 (purchased from LANXESS Corporation), 4307 (purchased from LANXESS Corporation), 4221 (purchased from LANXESS Corporation), and the like.

Apparently, other conventional components may be further added into the composition, to ameliorate
15 performance of the elastomeric material of the product, wherein the components that may be added include, but are not limited to, one or more of the following:

(1) Crosslinker

A cross-linker is mainly used for the generation of free radicals, thereby initiating a cross-linking reaction, to allow very good cross-linking to occur both between the butyronitrile rubbers, and between the butyronitrile
20 rubber and the grafted graphite.

Preferably, the cross-linkers that may be used in the composition according to an example of the present invention include peroxide cross-linkers (for example, dicumyl peroxide), ester cross-linkers (for example, triallyl isocyanurate), sulfur cross-linkers, and the like.

Preferably, in the composition, the cross-linker has a content by weight percentage from 2.5% to 4%.

25 (2) Plasticizer

A plasticizer is used for the reduction of intermolecular acting forces of the elastomeric material of the product, thereby reducing their hardness, increasing their plasticity and flowability, and the like. In particular, in order to reduce the stress concentration and vibration transmission of a mobile element, the hardness of the elastomeric layer according to examples of the present invention should not be too high,
30 wherein a plasticizer should be used to advantage.

In particular, plasticizers that may be used in the composition according to examples of the present invention include polyester-type plasticizers, polyether-type plasticizers, and the like. In general, in the composition, the plasticizer may have a content by weight percentage from 4% to 10%.

Because the elastomeric material of the present invention is preferably used in a one-way valve of a
35 compressor, it will contact refrigerant, oil and the like, and a lot of existing plasticizers may be dissolved in the refrigerant, oil and the like and gradually lose efficacy, resulting in changes in hardness, size and the like of the elastomeric material, which is thus not applicable. It is found via studies that the TP-759-type plasticizer is minimally influenced by the refrigerant and oil, and thus is particularly suitable for use in the present invention.

The TP-759-type plasticizer is a high-compatibility mixed plasticizer of polyester and polyether, produced by the Rohm and Haas Company, USA.

(3) Anti-aging agent

An anti-aging agent is mainly used for delaying the aging process of an elastomeric material, and prolonging its service life.

In particular, anti-aging agents that may be used in the composition according to examples of the present invention include 2,4-trimethyl-1,2-dihydro-quinoline polymers and the like.

(4) Promoter

A promoter is mainly used for increasing the reaction rate.

In particular, promoters that may be used in the composition according to examples of the present invention include: thioaminos, such as, zinc dibutyl dithiocarbamate; thiurams, such as, monothiotetramethyl thiuram, hexathio (or tetrathio) bispentamethyl thiuram; sulphenamides, such as, N-cyclohexyl-2-benzothiazole sulphenamide, N-dicyclohexyl-2-benzothiazole sulphenamide, and the like. Of course, the promoter applied particularly may be any one, or a combination of more than one of the above.

(5) Filler

A filler is generally an inorganic matter powder, for use in filling in a base material, to change the overall mechanical performance of a material or reduce the cost.

In particular, fillers that may be used in the composition according to examples of the present invention include carbon black, pottery clay, talc powder, calcium carbonate, and the like.

(6) Aid

Aids include a variety of different types, including, but not limited to: reaction aids for promoting reaction, such as, zinc oxide, magnesium oxide, etc.; moulding aids for helping with moulding, such as, polyethylene glycol, etc.; and processing aids for helping with improving the processing performance, such as, stearic acid, etc.

Wherein, the composition may be obtained by directly mixing each of the above components according to a conventional method, which is not described in detail herein.

Elastomeric material

An example of the present invention further provides an elastomeric material, which is formed by cross-linking the above composition.

In particular, in a basic method for forming the elastomeric material by cross-linking the above composition, each of the components is molten by heating and subjected to cross-linking reaction, with a heating temperature from about 100°C to 200°C, for a time period of several tens of minutes to several hours. The particular manufacture processes thereof include conventional methods such as milling, hot pressing, and extrusion, which are not described in detail herein.

In order for the comparability of results, in each example of the present invention, elastomeric materials are prepared according to the following process uniformly. The composition is subjected to

cross-linking by hot pressing for 10 min at a temperature of 170°C and a pressure of 10 MPa; and then heating is carried out for 4 h in a heating furnace at a temperature of 140°C.

Examples

Different elastomeric materials and one-way valves were prepared below according to the above formulae and preparation methods, as examples and comparative examples of the present invention, to illustrate the present invention exemplarily.

1. Material statement

The name, ingredient, parameter, source and the like of substances employed in each example are as shown in the following table:

Table 1. A list of parameters of raw materials employed in examples of the present invention

Name		Classification	Ingredient and property	Source
F09		Raw material graphite for preparation of grafted graphite	Colloid graphite with an average particle diameter of 10 μm	Qingdao Baichuan Graphite Co., Ltd.
LNBR-NH ₂		Raw material butyronitrile rubber for preparation of grafted graphite (i.e., a copolymer of butadiene and acrylonitrile)	Amino-terminated butyronitrile rubber in a liquid state, with a weight average molecular weight of 1300, a density of 0.85 g/cm ³ , and a solid content of 99 wt%	EMERALD Company, USA
BPO		Strong oxidizer for preparation of grafted graphite	Benzoyl peroxide	Akzo Nobel Company
DCC		Catalyst for preparation of grafted graphite	Dicyclohexyl carbodiimide	Shanghai Nuotai Chemical Company
DMF		Solvent for preparation of grafted graphite	N,N-dimethyl formamide	Sinopharm Chemical Reagent Co., Ltd.
4307		Butyronitrile rubber for use in the composition	Hydrogenated butyronitrile rubber	LANXESS Corporation
P14-40		Crosslinker	Dicumyl peroxide	Akron Company
TAIC		Crosslinker	Triallyl isocyanurate	Huaxing Chemical Co., Ltd.
TP-759		Plasticizer	Mixed plasticizer of polyester and polyether	Rohm and Haas Company, USA
RD		Anti-aging agent	2,2,4-trimethyl-1,2-dihydro-quinoline polymer	Rhein Chemical Company
N550		Filler	Carbon black	Cabot Company, USA
ZnO		Reaction aid	Zinc oxide	Lianlain Chemical Company
MgO		Reaction aid	Magnesium oxide	Lianlain Chemical Company
PEG4000		Moulding aid	Polyethylene glycol	Lotte Chemical, Korea
SA		Processing aids	Stearic acid	Rugao Shuangma Chemical Company
BM-1-HC-600		Binder for binding the elastomeric layer	Rubber-type binder	Chemlok Company
JL-250		Binder for binding the elastomeric layer	Rubber-type binder	Chemlok Company
Thixon 520-P-EF		Binder for binding the elastomeric layer	Rubber-type binder	Rohm and Haas Company, USA
Thixon P-11-EF		Binder for binding the elastomeric layer	Rubber-type binder	Rohm and Haas Company, USA
CH205		Binder for binding the elastomeric layer	Rubber-type binder	Chemlok Company

2. Testing methods

The elastomeric materials and one-way valves of each example and comparative example should be subjected to some performance tests, with particular testing methods as follows:

(1) Peel stress test

The elastomeric layer is peeled off from the basal body along a direction at 180° with respect to the binding surface using a tensile machine (purchased from Instron Company) to test its stress as the peel stress.

(2) Impact simulation

Stress distribution, vibration situation, maximum stress, peak impact pressure, opening degree, flow rate of fluid and the like of the valve plate in a run process of a one-way valve are simulated and calculated using an Abaqus Finite Element Software from Dassault Systèmes, France.

(3) Test of mechanical performance

Each mechanical performance of the elastomeric material is tested, including:

Tensile strength: the elastomeric material is fabricated into type 1 samples according to Chinese National Standard GB/T528, wherein, the samples are dumbbell type, with a thickness of 2 ± 0.2 mm, a total length of 115 mm, a length of the middle narrow part of 33 ± 2 mm, a width of the narrow part of 6 ± 0.4 mm, the narrow part is connected with the front end through two circular arcs that are interconnected and opposite in direction, the circular arc close to the narrow part has a knuckle radius of 14 ± 1 mm, and the circular arc close to the front end has a knuckle radius of 25 ± 2 mm. The samples are stretched at a rate of 500 mm/min and tested for the maximum stress in the stretching process as the tensile strength, using a Model 3365 tensile machine (purchased from Instron Company).

Extension at break: the elastomeric material is fabricated into the above type 1 samples, and stretched at a rate of 500 mm/min using the Model 3365 tensile machine (purchased from Instron Company), and the strain at break is taken as the extension at break.

Hardness: the elastomeric material is fabricated into the above type 1 samples, and tested for surface hardness thereof using a Model XL-A Shore A hardness scale (purchased from Shanghai Liuling Instrument Plant), an average from 3 times of the test at different positions for each sample is taken as a result.

(4) Test of aging resistance

The above type 1 samples are soaked in an analog solution for 40 days at a pressure of 20 bar and a temperature of 140°C, and then observed and tested, to judge the aging resistance thereof.

Wherein, the analog solution is used to simulate the environment within a compressor, and consists of oil and refrigerant blended together, wherein the oil has types of 4GSI and 410W (both purchased from Sun Company, Japan), with a ratio by weight of the two at 100: 15; and the refrigerant has a model of R22 (purchased from Dupont Company), and a ratio by weight of the refrigerant to the oil (total amount) is 100: 13.

After completion of the soaking, aging resistance of the sample elastomeric materials is judged according to the following indexes:

whether the surface has cracking or foaming, preferably none;

rate of change in the size, the increase amplitude is preferably within 5%;
rate of change in Shore hardness, the decrease amplitude is preferably within 15%; and
rate of change in tensile strength, the decrease amplitude is preferably within 20%.

Wherein, each "rate of change" refers to a relative proportion of the change in corresponding
performance of the material after the soaking, with performance of the material before the soaking as
100%.

(5) Test of dynamic aging resistance

The elastomeric layer will be deformed in the course of use due to the repeated impact by the valve
plate, thus the capacity of resisting repeated deformation (i.e., dynamic aging resistance) thereof is very
important, and a test of dynamic aging resistance includes:

The elastomeric material is fabricated into strip-shaped samples with a width of 25 mm, a length from
140 mm to 155 mm, and a thickness of 6.3 mm, and a semicircular groove through the width direction thereof
with a radius of 2.38 mm is processed on one side of the center along the length direction of the strip-shaped
sample.

Both ends of the strip-shaped sample are clamped on two clamping heads of a Model GT7011 De
Mattia deflection testing machine (purchased from Taiwan GOTECH Company), to allow the above
groove to be situated in the middle. When the testing machine is switched on, one of the clamping heads
moves back and forth in a "going away - going close" manner relative to the other clamping head, with
a stroke of 57 mm, a frequency of 5 Hz, and a maximum distance between the two clamping heads of 75
mm. With the movement of the clamping head, the strip-shaped sample is also "bent - straightened"
repeatedly. After a certain number of the cycle, the crack situation on the strip sample is observed, to
judge the grade of dynamic aging resistance, in particular as follows:

grade 1, there are only "acupuncture point" like cracks observed with naked eye, with a number not
exceeding 10;

grade 2, there are only "acupuncture point" like cracks observed with naked eye, with a number
greater than 10;

grade 3, there are "fissure" like cracks, and the maximum fissure length is greater than 0.5 mm and
not more than 1 mm;

grade 4, there are "fissure" like cracks, and the maximum fissure length is greater than 1 mm and
not more than 1.5 mm;

grade 5, there are "fissure" like cracks, and the maximum fissure length is greater than 1.5 mm and
not more than 3 mm;

grade 6, there are "fissure" like cracks, and the maximum fissure length is greater than 3 mm.

3. Examples and comparative examples

Various elastomeric materials and one-way valves were prepared selecting various raw materials and
formulae according to the above preparation method, as particular examples and comparative examples of
the present invention, and are subjected to corresponding performance tests.

Example 1:

The basal body (made of cold rolled steel) of the position-limiting element was cleaned with butanone and isopropanol, then coated with a binder in a thickness of about 30 μm , and dried in an environment at 60°C for 30 min. Then, hydrogenated butyronitrile rubber and the basal body bearing the binder were subjected to cross-linking (vulcanizing) for 10 min at a temperature of 160°C or 170°C, to form an elastomeric layer on a surface of the basal body. Subsequently, these elastomeric layers were tested for peel stress, with results thereof shown in the following table:

Table 2. Peel stress (N/mm) of elastomeric layers using different binders

Binder	BM-1-HC-600	JL-250	Thixon 520-P-EF	Thixon P-11-EF	CH205
Peel stress when cross-linked at 160°C	15.2	7.8	11.2	6.8	11.8
Peel stress when cross-linked at 170°C	17.8	9.2	12.8	7.2	12.1

It can be seen that, when the elastomeric layer is bonded to the basal body by a conventional binder, the peel stress thereof can all satisfy the above requirement of being greater than or equal to 0.6 Newton/millimeter.

Example 2:

Models of the one-way valves (having the elastomeric layer) according to examples of the present invention and the existing one-way valves (having no elastomeric layer) were established according to the above method of impact simulation tests, to simulate respectively stress, vibration situations and the like thereof in the course of use.

Wherein, a structure of the existing one-way valve model is as shown in FIGs. 1 and 2, with particular size parameters as follows:

thickness of the position-limiting part: 2.5 mm;

curvature of a lower surface of the position-limiting part: $1/150 \text{ (mm}^{-1}\text{)}$;

angle between the root of the position-limiting part and the valve body: 3.257°;

thickness of the valve plate: 0.152 mm;

length of the mobile part of the valve plate: 14 mm;

width of the mobile part of the valve plate: 7.6 mm;

working frequency: 50 Hz.

In the simulation, the position-limiting part was made of a cold rolled steel material, the valve plate was made of a spring steel material, and the two materials had mechanical parameters used in the simulation respectively of:

cold rolled steel: Young's modulus 193 GPa, tensile strength 505 MPa, and extension at break 70%;

spring steel: Young's modulus 210 GPa, tensile strength 1500 MPa, extension at break 8%.

A structure of the one-way valve model according to an example of the present invention is as shown in FIGs. 6 and 7, and is similar to the existing one-way valve, and has difference in that the position-limiting

part thereof includes the above elastomeric layer. In particular, the basal body of the position-limiting part may be directly provided thereon with a monolayer of the elastomeric layer, and in this case the elastomeric layer has a thickness of 0.6 mm, and employs a hydrogenated butyronitrile rubber or silica gel material. Alternatively, the basal body may also essentially has a stack structure including an elastomeric layer located on the inner side (close to the basal body) and a rigid layer located on the outer side (away from the basal body), wherein a hydrogenated butyronitrile rubber material is employed as the elastomeric layer, with a thickness of 0.5 mm, and the above cold rolled steel material is employed as the rigid layer, with a thickness of 0.8 mm.

In the simulation, the elastomeric layer material had mechanical parameters of:

hydrogenated butyronitrile rubber: Young's modulus 6 MPa, tensile strength 18.3 MPa, and extension at break 250%;

silica gel: Young's modulus 3 MPa, tensile strength 6.5 MPa, and extension at break 500%.

FIG. 9 and FIG. 10 are respectively mimic distribution diagrams of the maximum stress suffered by each part of the valve plates of an existing one-way valve and a one-way valve having a monolayer of the hydrogenated butyronitrile rubber elastomeric layer according to an example of the present invention, in one motion cycle. It can be seen that, after the addition of the elastomeric layer, the original stress concentration area in the middle part of the valve plate dissipates, indicating that the stress suffered by the valve plate in the movement process is sharply decreased, thereby prolonging service life of the valve plate and providing possibility of increasing the opening degree of the valve plate.

FIG. 11 and FIG. 12 are respectively mimic diagrams of vibration situations of an existing one-way valve and a one-way valve having a monolayer of the hydrogenated butyronitrile rubber elastomeric layer according to an example of the present invention, in one motion cycle. It can be seen that, after the addition of the elastomeric layer, the vibration of the valve plate itself is sharply decreased, thereby prolonging service life of the valve plate, and reducing the fluid disturbance and increasing the flow rate of fluid.

The following table shows simulation results of a part of performances in the movement process of the valve plate. It can be seen that, after the addition of the elastomeric layer, the maximum impact force and maximum stress suffered by the valve plate are decreased by -55.8% and -34.5% respectively, and correspondingly, the opening degree thereof and the fluid (refrigerant) flow rate through the one-way valve are increased by 7.37% and 5.9% respectively, as compared with the one-way valve having no elastomeric layer. It can be seen therefrom that, the presence of the elastomeric layer can sharply reduce the impact suffered by the valve plate, so that vibration and noise are decreased, service life of the valve plate is prolonged, and at the same time the flow rate of fluid through the one-way valve is increased, thereby improving energy efficiency of the compressor.

Table 3. Simulation results of one-way valves without an elastomeric layer and with a monolayer of the hydrogenated butyronitrile rubber elastomeric layer

Items	Without the elastomeric layer	With a monolayer of the hydrogenated butyronitrile rubber elastomeric layer
Maximum impact force suffered by the valve plate	75.6 N	33.4 N
Maximum stress of the valve plate	473.213 MPa	309.761 MPa
Opening degree of the valve plate	3.133 mm	3.364 mm
Flow rate of fluid	2.657 kg/h	2.813 kg/h

The following table shows simulation results of the one-way valve using a monolayer of hydrogenated butyronitrile rubber and a monolayer of silica gel as the elastomeric layers. It can be seen that, use of other elastomeric materials such as silica gel as the elastomeric layer may also exert a cushioning effect, indicating that the elastomeric layer of the present invention is not limited to the hydrogenated butyronitrile rubber.

Table 4. Simulation results of one-way valves with a monolayer of hydrogenated butyronitrile rubber elastomeric layer or a monolayer of silica gel elastomeric layer

Items	With a monolayer of silica gel elastomeric layer	With a monolayer of hydrogenated butyronitrile rubber elastomeric layer
Maximum impact force suffered by the valve plate	31.5 N	33.4 N
Maximum stress of the valve plate	327.24 MPa	309.761 MPa
Opening degree of the valve plate	3.361 mm	3.364 mm

Table 5. Simulation results of one-way valves without an elastomeric layer, with a monolayer of hydrogenated butyronitrile rubber elastomeric layer, with a stack structure

Items	Without the elastomeric layer	With a monolayer of hydrogenated butyronitrile rubber elastomeric layer	With a tack structure
Maximum impact force suffered by the valve plate	75.6 N	33.4 N	36.4 N
Time for the valve plate to move to position	0.002052 s	0.002069 s	0.002066 s

It can be seen from the above table that, the valve plates when using a monolayer of the elastomeric layer and a stack structure have impact forces all less than those without the elastomeric layer, and have time for the valve plate to move to position all greater than those without the elastomeric layer, indicating that the valve plate has prolonged movement process, and reduced impact force suffered. Therefore, both of the two situations can exerted a cushioning effect. In contrast, the one-way valve using a monolayer of the elastomeric layer suffers from a force lower than that of the one-way valve using a stack structure, indicating that after the addition of the rigid layer, the cushioning effect of the valve plate is reduced somewhat, but is still superior to that without the elastomeric layer.

Examples 3 to 12, Comparative examples 1 and 2:

As described above, the one-way valve of the present invention is preferably used in a one-way valve of a compressor, and such one-way valve will be located in a complex environment of high temperature, high pressure, and high corrosion (refrigerants and oils), so that wherein the elastomeric layer material should have capacity of resisting to the above environment.

Various grafted graphites were prepared according to the above preparation methods as well as formulae in the following tables, for use in the preparation of various elastomeric materials.

Table 6. Parameters of grafted graphite (amounts used are all in parts by weight)

No.	Grafted graphite 1	Grafted graphite 2	Grafted graphite 3	Comparative graphite
Amount of F09 used	100	100	100	100
Amount of DMF used	400	400	400	400
Amount of LNBR-NH ₂ used	20	40	25	10
Amount of DCC used	1	1	2	1
Graft amount	0.09	0.17	0.12	0.02

5

Wherein, the amount of each substance used refers to the amount of the substance employed in each step when the grafted graphite is prepared according to the above method. The graft amount is a ratio by weight of graft groups to graphite particles in the product of grafted graphite, which is obtained by calculation according to the gain in weight of the product of grafted graphite with respect to the raw material graphite, because the gain in weight may be regarded approximately as the weight of the graft groups.

10

Wherein, when the comparative graphite is prepared, the amount of butyronitrile rubber used and the final graft amount are both less than the preferred ranges in the present invention, so that it is used as the comparative example.

15

The grafted graphite was prepared into compositions of various examples or comparative examples according to the formulae in the following table, and these compositions were formed into elastomeric materials according to the above method, then each elastomeric material was tested for performance according to the above methods.

20

Table 7. Composition formulae (amounts of the substances used are all percentages by weight in the composition)

No.	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10	Example 11	Example 12	Comparative example 1	Comparative example 2
4307	30%	42%	50%	28%	42%	60%	30%	50%	50%	50%	50%	50%
P14-40	3%	3%	2%	3%	2.5%	2%	3%	2%	2%	2%	2%	2%
TP-759	7%	6%	4%	9%	5%	5%	8%	4%	4%	4%	5%	4%
RD	1.5%	2%	1%	1.5%	2%	0.5%	1.5%	1%	1%	1%	1%	1%
N550	38%	38%	29%	39%	38%	24%	38%	29%	29%	29%	35.5%	29%
PEG4000	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
ZnO	3%	2%	2%	3%	2%	2%	3%	2%	2%	2%	2%	2%
TAIC	1%	1%	0.5%	1%	1%	0.5%	1%	0.5%	0.5%	0.5%	0.5%	0.5%
SA	1%	1%	0.5%	1%	1%	0.5%	1%	0.5%	0.5%	0.5%	0.5%	0.5%
MgO	1.5%	1%	1.5%	1.5%	1%	1.0%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Grafted graphite	12%	2%	7.5%	11%	3.5%	2.5%	11%	7.5%	7.5%	7.5%	None	7.5%
Type of grafted graphite	Grafted graphite 2	Grafted graphite 2	Grafted graphite 2	Grafted graphite 2	Grafted graphite 2	Grafted graphite 2	Grafted graphite 2	Grafted graphite 1	Grafted graphite 2	Grafted graphite 3	None	Comparative graphite
Shore A hardness	69	67	65	69	73	70	68	63	65	63	72	62
Tensile	16.8	18	17.2	15.5	23	14.2	14.5	14.3	16.7	15.1	21.5	11.6

strength (MPa)												
Extension at break (%)	580	530	550	460	500	620	580	610	570	620	475	643

It can be seen from the above table that, performances such as hardness, tensile strength, and extension at break of the elastomeric materials containing grafted graphite according to Examples 3 to 12 of the present invention all meet the requirements, and the elastomeric materials can be used as the material of the above elastomeric layer.

It can be seen from Comparative example 2, where the comparative graphite with a lower graft amount is used, the corresponding elastomeric material has tensile strength of only 11.6 MPa, which is evidently lower than that of the elastomeric material according to examples of the present invention. It is indicated that, if the graft amount of the grafted graphite is too low (or not grafted at all), the graphite cannot be blended into the elastomeric material well, but instead will cause adverse effects on performance such as strength of the elastomeric material, which is thus not applicable. On the contrary, the grafted graphite according to examples of the present invention may be co-crosslinked with butyronitrile rubber, to eliminate the interface between graphite particles and the butyronitrile rubber, thereby blending well into the butyronitrile rubber, and thus no adverse effect will be caused to performance such as strength of the elastomeric material.

Other performance of the elastomeric material of the above examples will be described in detail below.

An existing butyronitrile rubber (unhydrided butyronitrile rubber, type 230S, purchased from JSR Company, Japan), an existing hydrogenated butyronitrile rubber (type 4307, purchased from LANXESS Corporation), and the elastomeric material according to Example 3 of the present invention were subjected to the above tests for aging resistance.

FIGs. 13, 14, and 15 show respectively photographs of surface topography after the above tests for aging resistance, of the existing butyronitrile rubber, the existing hydrogenated butyronitrile rubber, the elastomeric material according to Example 3 of the present invention. It can be seen that, the elastomeric material according to Example 3 of the present invention has hardly any cracking, foaming or the like on the surface. On the contrary, both the existing butyronitrile rubber and hydrogenated butyronitrile rubber have foaming on the surfaces, but an ordinary unhydrided butyronitrile rubber (230S) has foaming severer than that of the hydrogenated butyronitrile rubber (4307).

FIGs. 16 and 17 show respectively comparative photographs of the size before and after the tests for aging resistance, of the existing hydrogenated butyronitrile rubber, and the elastomeric material according to Example 3 of the present invention. Under a circumstance one side of the materials are aligned, the difference in position on the other side stands for the size expansion after the tests for aging resistance. It can be seen that, the elastomeric material according to Example 3 of the present invention has tiny size expansion after the tests for aging resistance, whereas the existing hydrogenated butyronitrile rubber has evident size expansion.

The above results indicate that:

First, the elastomeric material according to the example of the present invention has good aging resistance, and both the existing butyronitrile rubber and hydrogenated butyronitrile rubber have poorer aging resistance than that of the elastomeric material of the present invention.

Second, the existing hydrogenated butyronitrile rubber has aging resistance in turn better than that of an ordinary unhydrided butyronitrile rubber. It proves that hydrogenation of butyronitrile rubber facilitates increase in the aging resistance thereof. It can be seen therefrom that, both in the elastomeric material of the present invention, and in the preparation process of the grafted graphite, the use of hydrogenated butyronitrile rubber as a raw material is more preferred.

Table 8. Aging resistance of elastomeric materials

No.	Comparative example 1	Example 3	Example 4	Example 5
Foaming	None	None	None	None
Cracking	None	None	None	None
% Rate of change in size	12	5	8	7
% Rate of change in Shore hardness	-20	-11	-14	-13
% Rate of change in tensile strength	-25	-6	-10	-9

The above table shows results of aging resistance tests performed on elastomeric materials from each example and comparative example of the present invention according to the above method. It can be seen that, rates of change in the size, hardness, and tensile strength of the elastomeric material containing no grafted graphite from Comparative example 1 after the aging resistance test are all evidently greater, with respect to those of the elastomeric materials containing grafted graphite from each example of the present invention, indicating that if no grafted graphite is contained, performance of the material will be deteriorated rapidly in an environment of refrigerant and oil. That is to say, the elastomeric material containing grafted graphite according to the examples of the present invention has indeed stronger resistance to refrigerant and oil, i.e., better aging resistance, and is thus preferably used as the elastomeric layer in a one-way valve of a compressor.

According to the above method, the elastomeric materials from each example and comparative example of the present invention were tested for dynamic aging resistance, with results thereof as shown in the following table.

Table 9. Dynamic aging resistance of elastomeric materials

No.	Comparative example 1	Comparative example 1 + 3% grafted graphite 3	Comparative example 1 + 6% grafted graphite 3	Comparative example 1 + 12% grafted graphite 3
Grade of dynamic aging resistance after 200,000 cycles	Grade 3	Grade 2	Grade 2	Grade 1
Grade of dynamic aging resistance after 600,000 cycles	Grade 5	Grade 4	Grade 2	Grade 2

Wherein, Comparative example 1 denotes the above elastomeric material containing no grafted graphite, and the later several examples denote elastomeric materials (equivalent to the elastomeric materials according to examples of the present invention) obtained by adding additionally 3%, 6%, and 12% by weight respectively

of grafted graphite 3, on the basis of the elastomeric material from Comparative example 1. It can be seen that, as the content of grafted graphite increases, the dynamic aging resistance of the elastomeric material also evidently increases, indicating that the elastomeric materials according to examples of the present invention have good dynamic aging resistance.

5 In summary, the position-limiting part of the one-way valve according to examples of the present invention is provided thereon with an elastomeric layer, which can play a role in cushioning and damping, thereby reducing the stress and vibration suffered by the valve plate, prolonging service life of the valve plate, reducing noise, allowing the opening degree of the valve plate to increase, thereby increasing the flow rate of fluid through the one-way valve, and ameliorating energy efficiency of the compressor.

10 At the same time, various mechanical performances of the elastomeric materials according to examples of the present invention are all in compliance with the requirements as an elastomeric layer, and both aging resistance and dynamic aging resistance thereof are also very good, thus it may be preferably used as a material of the elastomeric layer of a one-way valve in a compressor.

15 It can be understood that, the above embodiments are only exemplary embodiments employed for the illustration of principles of the present invention, but do not limit the present invention. For those of ordinary skill in the art, various variations and modifications may be made without departing from the spirit and essence of the present invention, which are also considered as falling within the protection scope of the present invention.

Claims

1. A limit element for a one-way valve, arranged on one end of a moving element of a one-way valve for limiting the open position of the moving element, wherein
the limit element is provided with an elastomer layer on the side in contact with the moving element, and
5 the elastomer layer is made of elastomer material.

2. The limit element for a one-way valve according to claim 1, wherein
the elongation at break of the elastomer material is at least 10%.

3. The limit element for a one-way valve according to claim 2, wherein
the stress of the elastomer material at a tensile strain of 10% is at least 0.5 MPa.

4. The limit element for a one-way valve according to claim 1, wherein
the Shore A hardness of the elastomer material at 23°C is 30 to 80.

5. The limit element for a one-way valve according to claim 4, wherein
the Shore A hardness of the elastomer material at 23°C is 30 to 70.

6. The limit element for a one-way valve according to claim 1, wherein
the elastomer material is damping rubber.

7. The limit element for a one-way valve according to claim 1, wherein
the elastomer material comprises any one of or combination of polyamide, polyurethane,
polyolefine, polyolefine derivatives, thermoplastic vulcanized rubber, fluoroelastomer, acrylic rubber,
epoxy resin and phenolic resin.

8. The limit element for a one-way valve according to claim 1, wherein the elastomer material is
formed from a composition through crosslinking, and the composition comprises:

nitrile butadiene rubber;

grafted graphite, comprising graphite particles and grafted groups which are grafted onto the
graphite particles, wherein the grafted groups comprise copolymer groups of butadiene and
acrylonitrile.

9. The limit element for a one-way valve according to claim 8, wherein
the weight percentage of the nitrile butadiene rubber in the composition is 28% to 60%;
the weight percentage of the grafted graphite in the composition is 2% to 12%.

10. The limit element for a one-way valve according to claim 8, wherein

in the grafted graphite, relative to the weight of the graphite particles, the weight ratio of the grafted groups is 6% to 20%.

11. The limit element for a one-way valve according to claim 1, wherein
the thickness of the elastomer layer is 0.1 mm to 5 mm.

12. The limit element for a one-way valve according to claim 11, wherein
the thickness of the elastomer layer is 0.5 mm to 1.5 mm.

13. The limit element for a one-way valve according to claim 1, wherein
the limit element comprises a substrate;
the elastomer layer is arranged at least on the side of the substrate in contact with the moving element.

14. The limit element for a one-way valve according to claim 13, wherein
the elastomer layer is bonded on the substrate, and the peeling stress along a direction of 180°
between the elastomer layer and the substrate is at least 0.6 N/mm.

15. The limit element for a one-way valve according to claim 13, wherein
the elastomer layer is clamped on the substrate, and the force for peeling off the elastomer layer
from the substrate is at least 30 N.

16. The limit element for a one-way valve according to claim 13, wherein
the elastomer layer is provided with a rigid layer on the side in contact with the moving element.

17. The limit element for a one-way valve according to claim 16, wherein
the thickness of the rigid layer is 0.01 mm to 4 mm.

18. The limit element for a one-way valve according to claim 16, wherein
the rigid layer is bonded on the elastomer layer, and the peeling stress along a direction of 180°
between the elastomer layer and the rigid layer is at least 0.6 N/mm.

19. The limit element for a one-way valve according to claim 1, wherein
the one-way valve is a one-way valve for a compressor, wherein the moving element is a valve plate,
and the valve plate comprises a fixed part connected to the valve body of the one-way valve and a moving
part moving relative to the valve body;
the limit element comprises a limit part used for limiting the open position of the valve plate.

20. The limit element for a one-way valve according to claim 19, wherein

the surface of the side of the limit part facing to the valve plate is a convex surface.

21. The limit element for a one-way valve according to claim 20, wherein when the limit element is arranged in the one-way valve, the curvature of the convex surface is $1/72 \text{ mm}^{-1}$ to $1/172 \text{ mm}^{-1}$ in the direction of the fixed part of the valve plate pointing to the moving part.

22. A limit element for a one-way valve of a compressor, arranged on one end of a valve plate of a compressor for limiting the open position of the valve plate, wherein

the limit element is provided with an elastomer layer on the side in contact with the valve plate, the elastomer layer is made of elastomer material, the elastomer material is formed from a composition through crosslinking, and the composition comprises:

nitrile butadiene rubber;

grafted graphite, comprising graphite particles and grafted groups which are grafted onto the graphite particles, wherein the grafted groups comprise copolymer groups of butadiene and acrylonitrile;

and

the weight percentage of the nitrile butadiene rubber in the composition is 28% to 60%;

the weight percentage of the grafted graphite in the composition is 2% to 12%;

in the grafted graphite, relative to the weight of the graphite particles, the weight ratio of the grafted groups is 6% to 20%.

23. The limit element for a one-way valve of a compressor according to claim 22, wherein

the thickness of the elastomer layer is 0.1 mm to 5 mm;

the valve plate comprises a fixed part connected to the valve body of the one-way valve and a moving part moving relative to the valve body;

the limit element comprises a limit part used for limiting the open position of the valve plate, and the surface of the side of the limit part facing to the valve plate is a convex surface; when the limit element is arranged in the one-way valve, the curvature of the convex surface is $1/72 \text{ mm}^{-1}$ to $1/172 \text{ mm}^{-1}$ in the direction of the fixed part of the valve plate pointing to the moving part.

24. A one-way valve, comprising:

a valve body with a valve bore;

a moving element arranged on one end of the valve body, used for moving between a closed position for closing the valve bore and an open position for leaving the valve bore;

a limit element arranged on one end of the moving element, used for limiting the open position of the moving element and provided with an elastomer layer on the side in contact with the moving element, wherein the elastomer layer is made of elastomer material.

25. The one-way valve according to claim 24, wherein the elastomer material is formed from a composition through crosslinking, and the composition comprises:

nitrile butadiene rubber;

5 grafted graphite, comprising graphite particles and grafted groups which are grafted onto the graphite particles, wherein the grafted groups comprise copolymer groups of butadiene and acrylonitrile.

26. The one-way valve according to claim 24, wherein

10 the one-way valve is a one-way valve for a compressor.

27. The one-way valve according to claim 26, wherein

the valve body comprises a first surface where the valve bore is formed;

15 the moving element is a valve plate comprising a fixed part and a moving part, the fixed part is connected to the first surface, and the moving part is used for moving between a closed position for covering the valve bore and an open position for leaving the valve bore;

the limit element comprises a limit part arranged on the side of the valve plate away from the first surface, and the distance between the limit part and the first surface increases gradually in the direction of the fixed part of the valve plate pointing to the moving part.

28. The one-way valve according to claim 27, wherein

the included angle between the tangent plane of the limit part in the position closest to the first surface and the first surface is 9° to 40°.

29. The one-way valve according to claim 27, wherein

25 the maximum distance between the side of the limit part close to the first surface and the first surface is 3 mm to 32 mm.

30. Grafted graphite, comprising graphite particles and grafted groups which are grafted onto the graphite particles, wherein the grafted groups comprise copolymer groups of butadiene and acrylonitrile.

31. The grafted graphite according to claim 30, wherein

relative to the weight of the graphite particles, the weight ratio of the grafted groups is 6% to 20%.

32. The grafted graphite according to claim 31, wherein

relative to the weight of the graphite particles, the weight ratio of the grafted groups is 6% to 17%.

33. The grafted graphite according to claim 30, wherein the grafted groups are hydrogenated copolymer groups of butadiene and acrylonitrile.

34. The grafted graphite according to claim 30, wherein the grafted groups are terminated copolymer groups of butadiene and acrylonitrile.

35. The grafted graphite according to claim 30, wherein the size of the graphite particles is 200 nm to 5000 nm.

36. A preparation method for grafted graphite, comprising:
functionalizing the graphite particles;
grafting the grafted groups onto the graphite particles to obtain the grafted graphite, wherein the grafted groups comprise copolymer groups of butadiene and acrylonitrile.

37. The preparation method for grafted graphite according to claim 36, wherein the graphite particles are functionalized by the following:

mixing the graphite particles and a strong oxidizer and heating the mixture to functionalize the graphite particles, wherein the strong oxidizer is any one of benzoyl peroxide, dicumyl peroxide, and potassium permanganate.

38. The preparation method for grafted graphite according to claim 36, wherein the grafted groups are grafted onto the graphite particles by the following steps:
scattering the graphite particles in N,N-Dimethylformamide to obtain a suspension;
adding the copolymer of butadiene and acrylonitrile and dicyclohexylcarbodiimide into the suspension;
heating the suspension to graft the grafted groups onto the graphite particles.

39. The preparation method for grafted graphite according to claim 38, wherein the copolymer of butadiene and acrylonitrile is a hydrogenated copolymer of butadiene and acrylonitrile.

40. The preparation method for grafted graphite according to claim 38, wherein the copolymer of butadiene and acrylonitrile is a terminated copolymer of butadiene and acrylonitrile.

41. The preparation method for grafted graphite according to claim 38, wherein in the suspension, relative to the weight of the graphite particles, the weight ratio of the copolymer of butadiene and acrylonitrile is 18% to 40%.

42. The preparation method for grafted graphite according to claim 38, wherein in the suspension, relative to the weight of the graphite particles, the weight ratio of N,N-Dimethylformamide is 350% to 450%, and the weight ratio of dicyclohexylcarbodiimide is 1% to 5%.

43. The preparation method for grafted graphite according to claim 38, wherein the suspension is heated by the following step:
heating the suspension at 80°C to 120°C for 20 to 28 hours.

44. A composition, comprising:
nitrile butadiene rubber;
grafted graphite, comprising graphite particles and grafted groups which are grafted onto the graphite particles, wherein the grafted groups comprise copolymer groups of butadiene and acrylonitrile.

45. The composition according to claim 44, wherein
the weight percentage of the nitrile butadiene rubber in the composition is 28% to 60%;
the weight percentage of the grafted graphite in the composition is 2% to 12%.

46. The composition according to claim 45, wherein
the weight percentage of the nitrile butadiene rubber in the composition is 30% to 50%;
the weight percentage of the grafted graphite in the composition is 3.5% to 7.5%.

47. The composition according to claim 44, also comprising:
crosslinking agent.

48. The composition according to claim 47, wherein
the crosslinking agent comprises any one or more of peroxide crosslinking agent, ester crosslinking agent and sulfur crosslinking agent.

49. The composition according to claim 47, wherein
the weight percentage of the crosslinking agent in the composition is 2.5% to 4%.

50. The composition according to claim 44, also comprising:
any one of or combination of plasticizer, antiager, accelerator and filler.

51. The composition according to claim 44, wherein
the nitrile butadiene rubber is hydrogenated nitrile butadiene rubber.

52. An elastomer material, formed from a composition through crosslinking, wherein the composition comprises:

nitrile butadiene rubber;

5 grafted graphite, comprising graphite particles and grafted groups which are grafted onto the graphite particles, wherein the grafted groups comprise copolymer groups of butadiene and acrylonitrile.

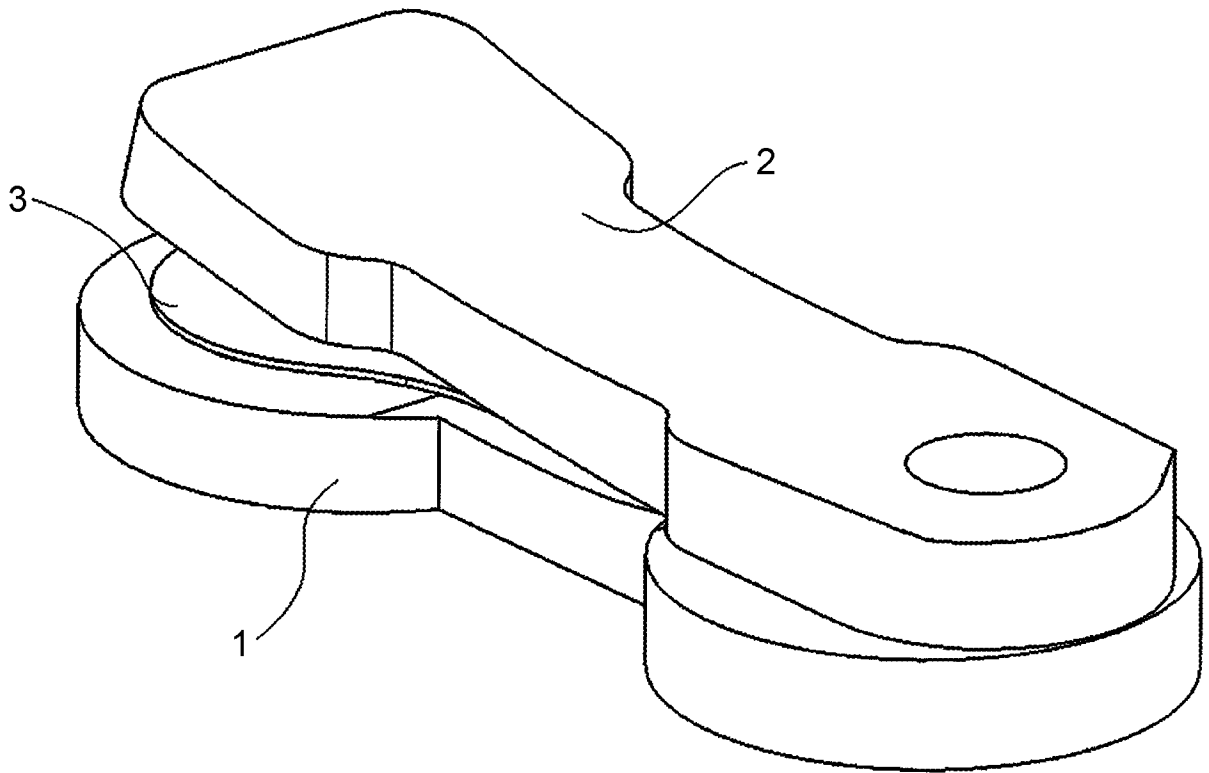


Fig. 1

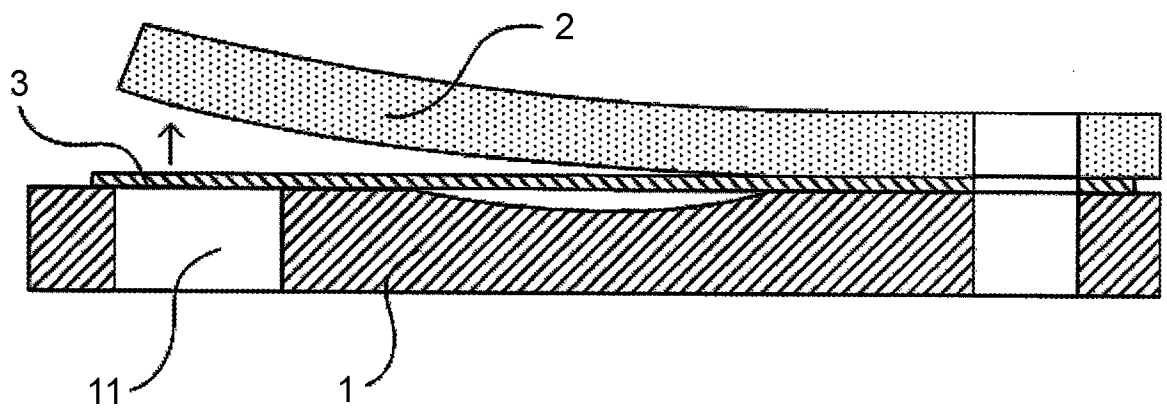


Fig. 2

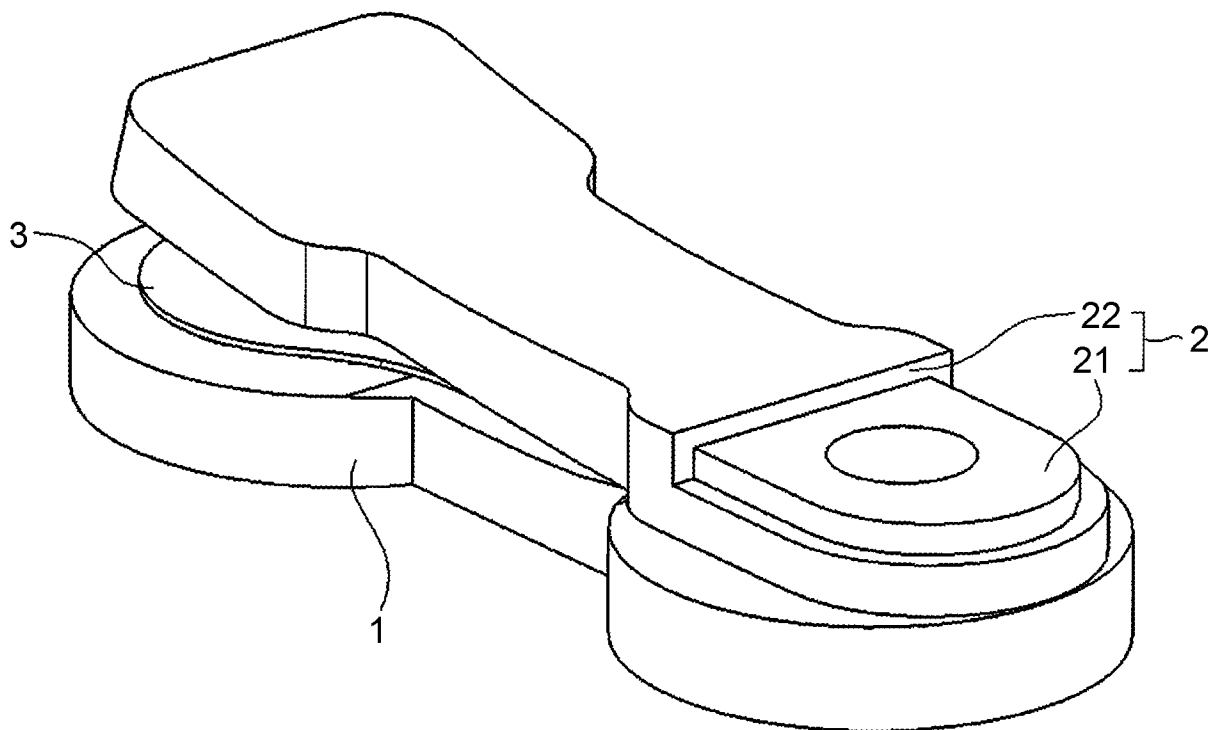


Fig. 3

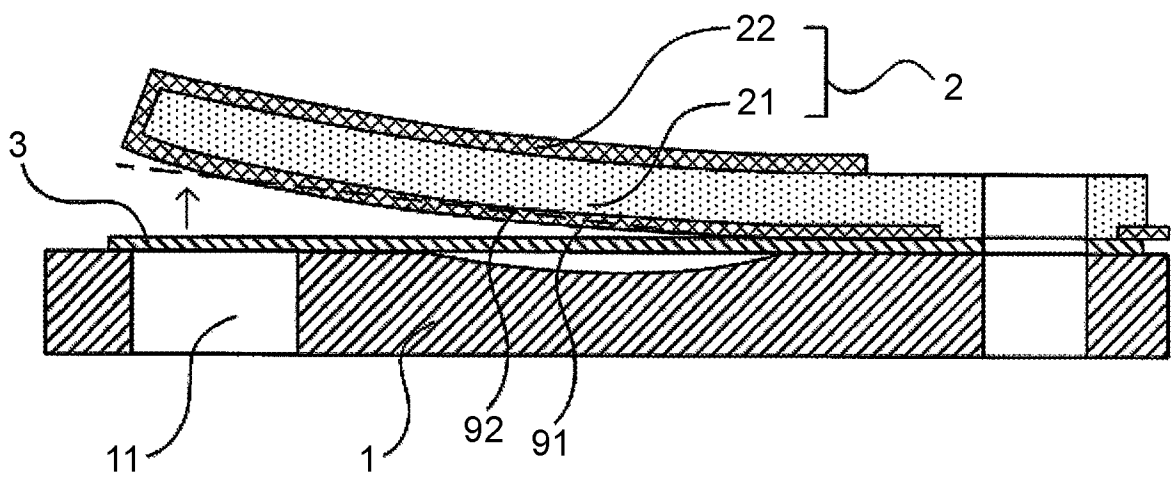


Fig. 4

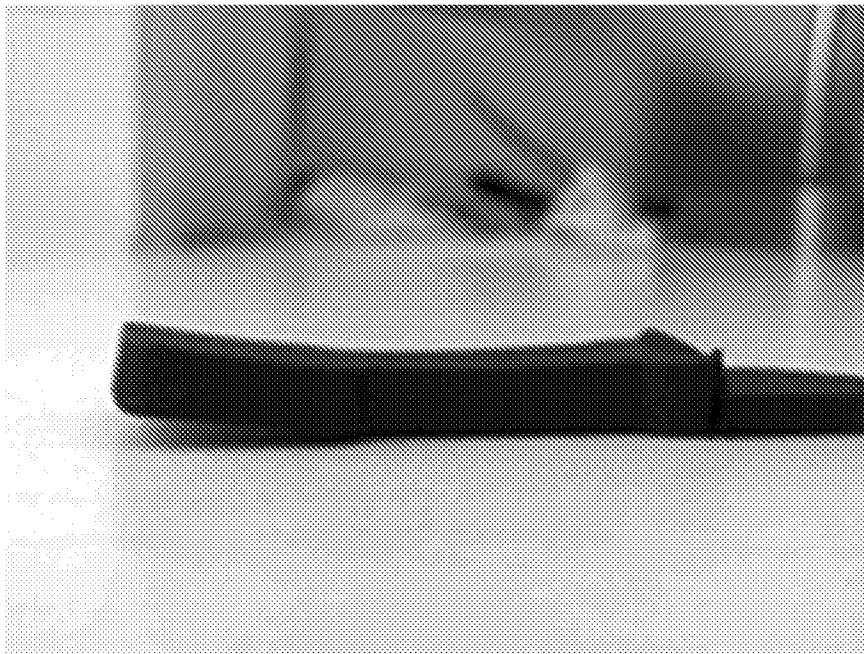


Fig. 5

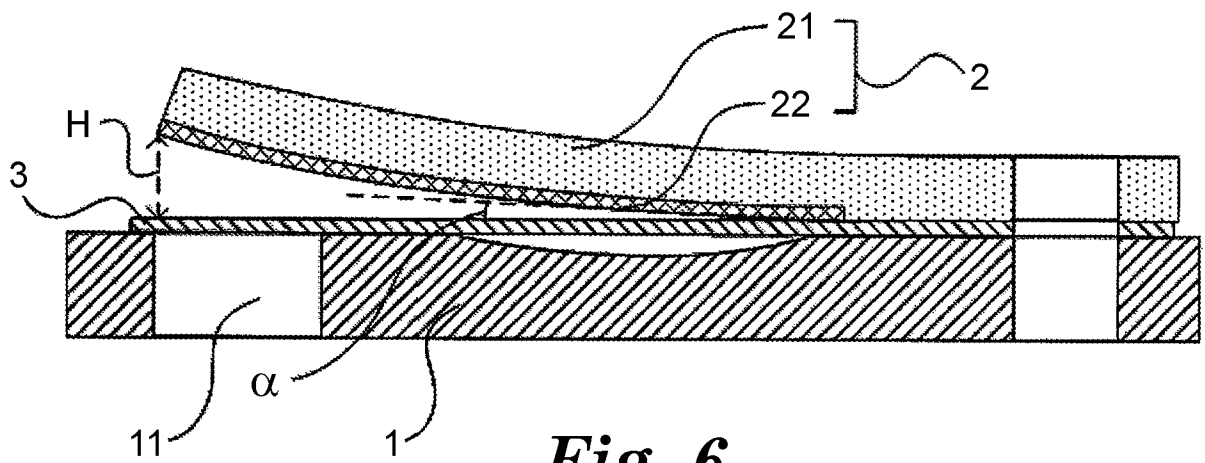


Fig. 6

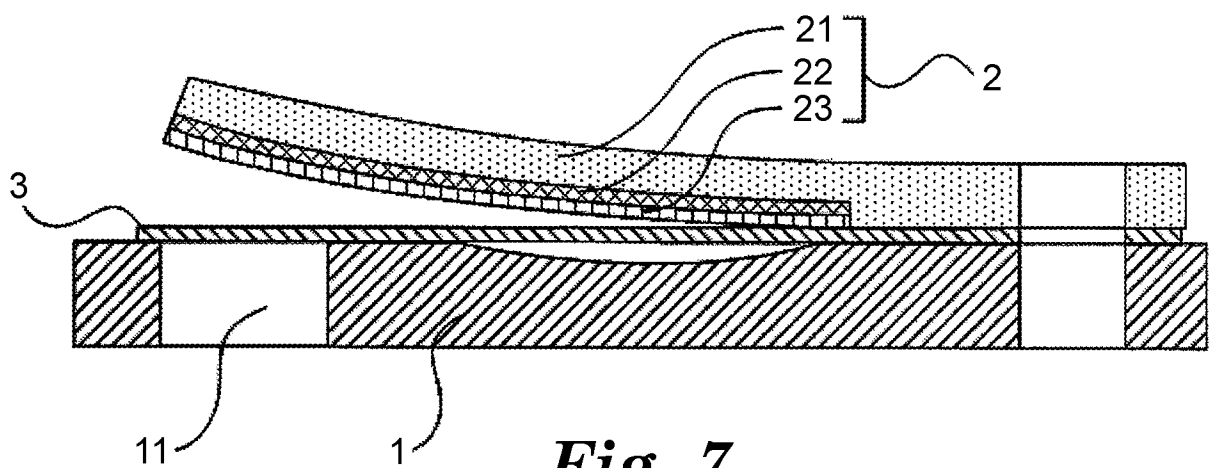
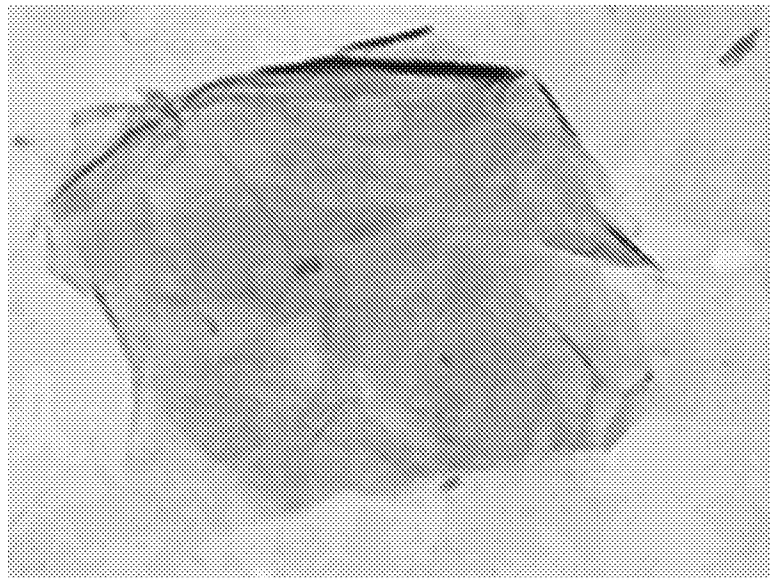


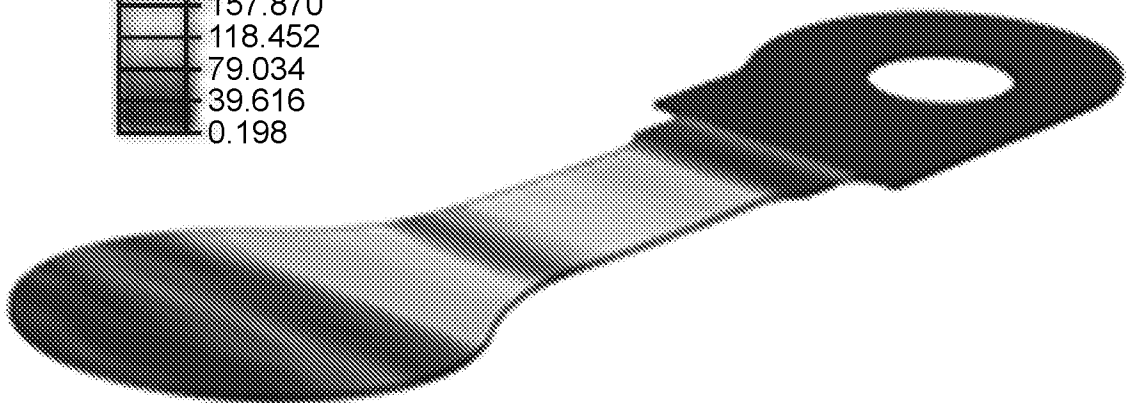
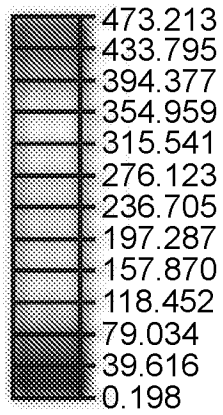
Fig. 7

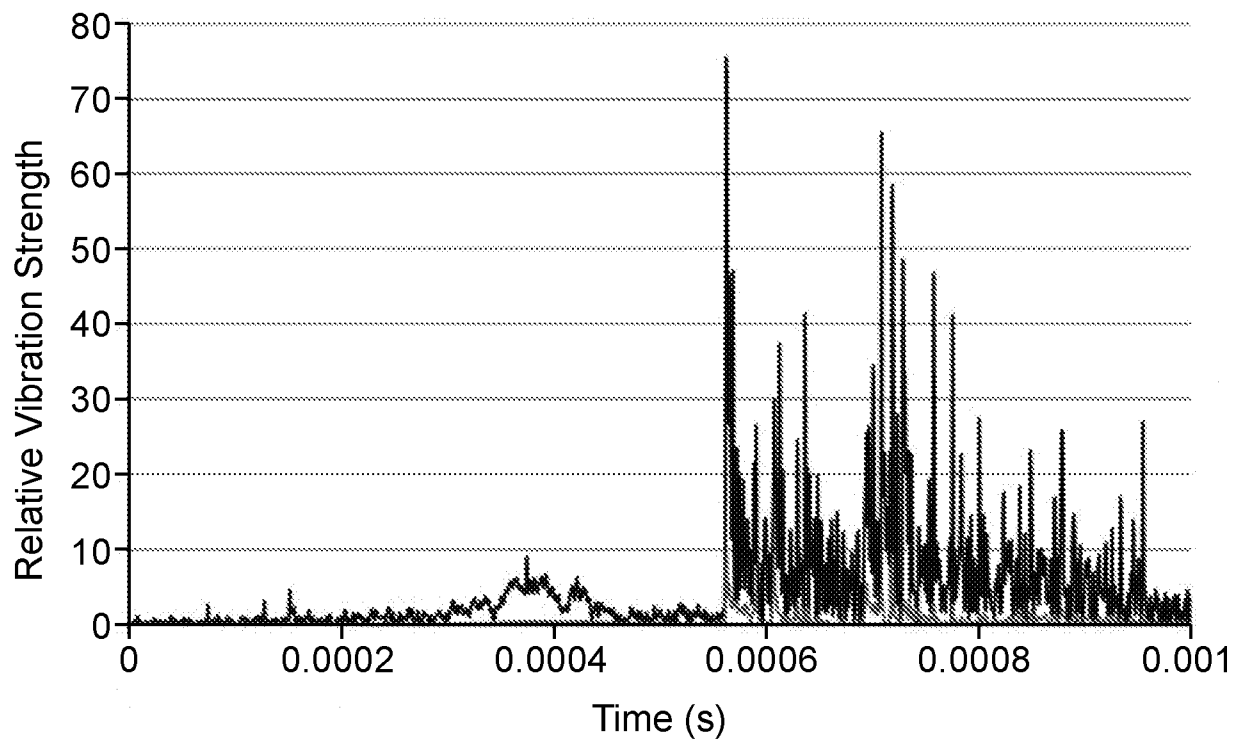
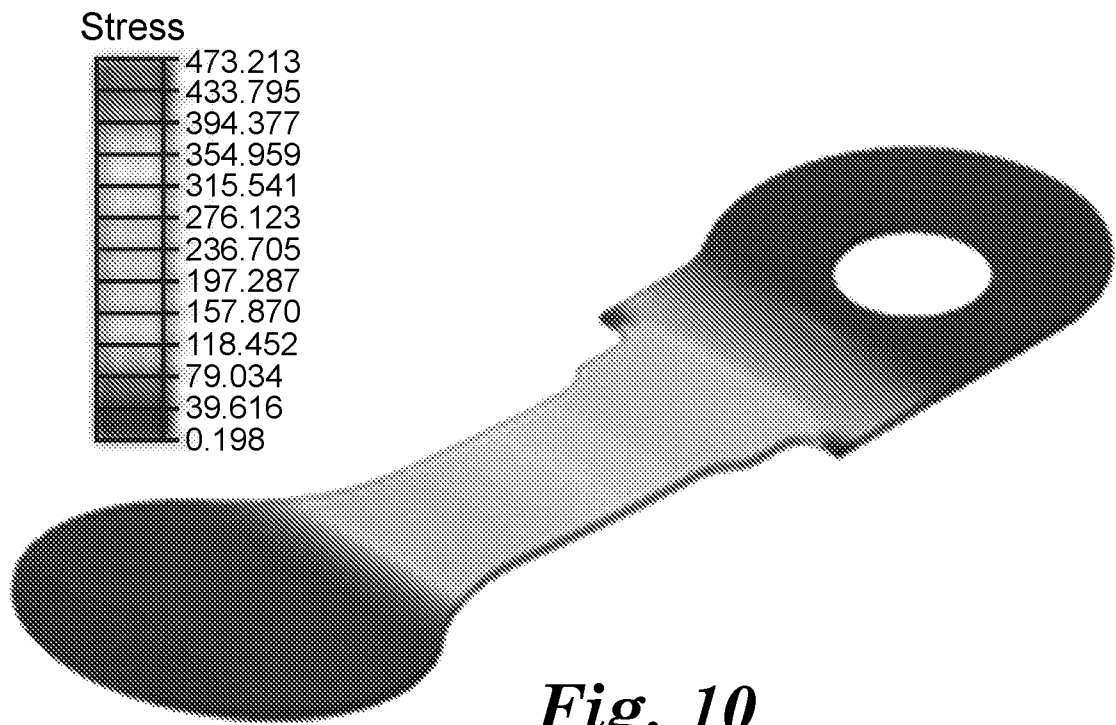


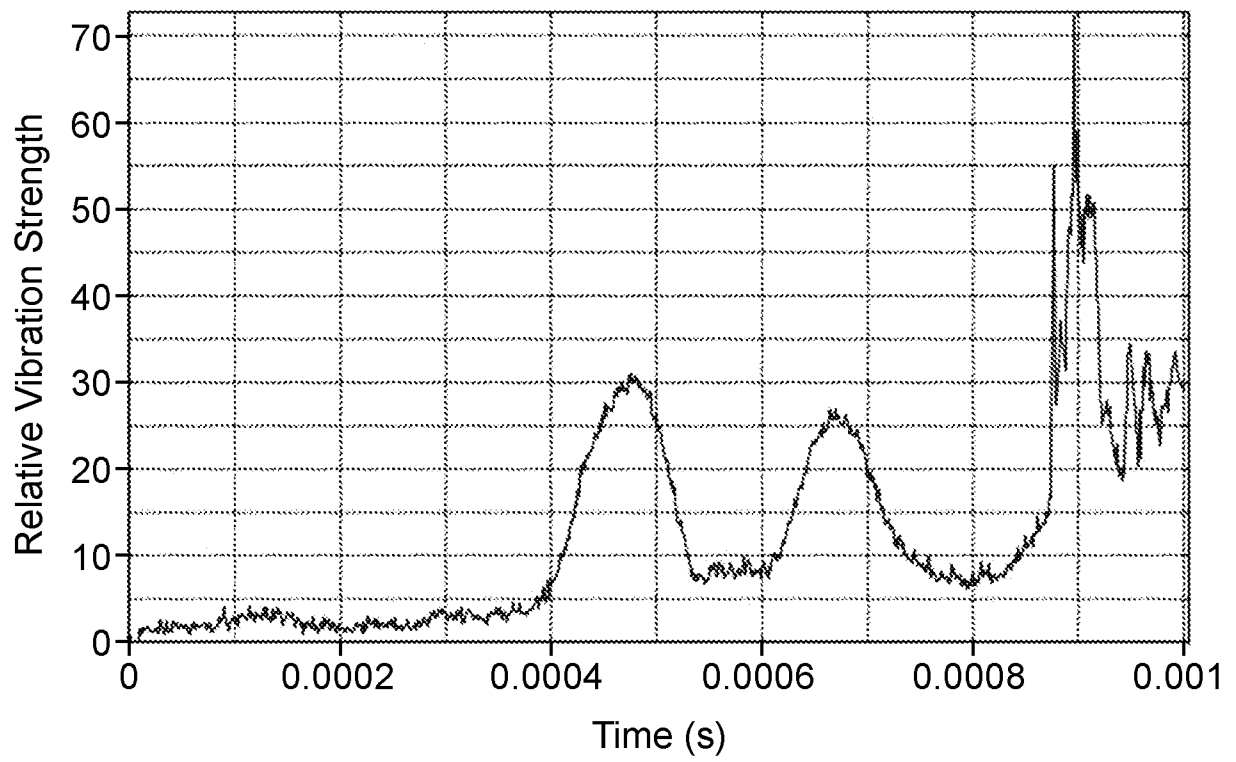
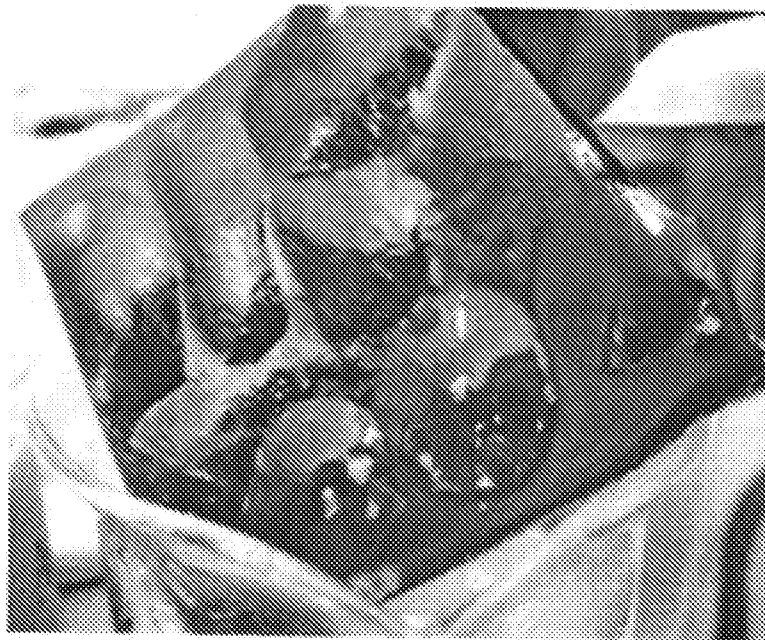
200mm

Fig. 8

Stress

*Fig. 9*



*Fig. 12**Fig. 13*

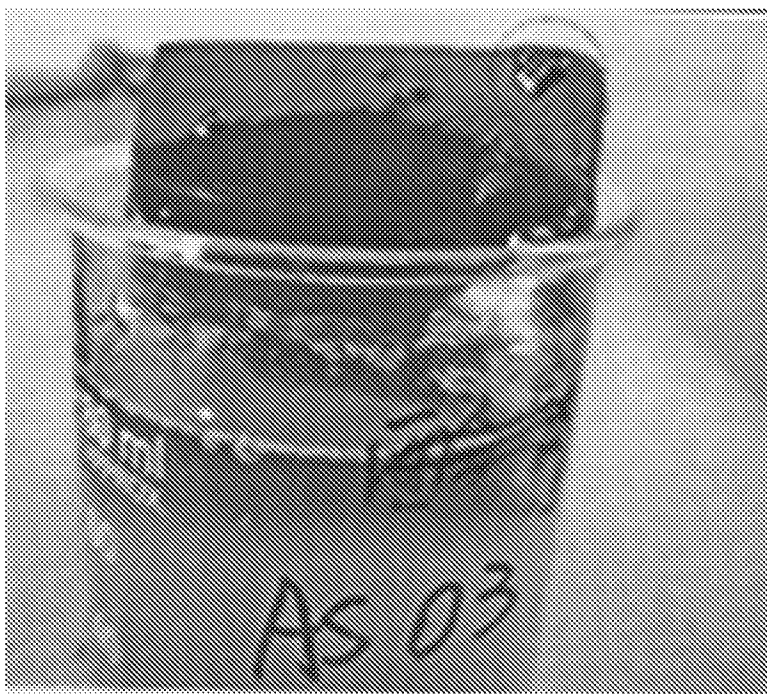
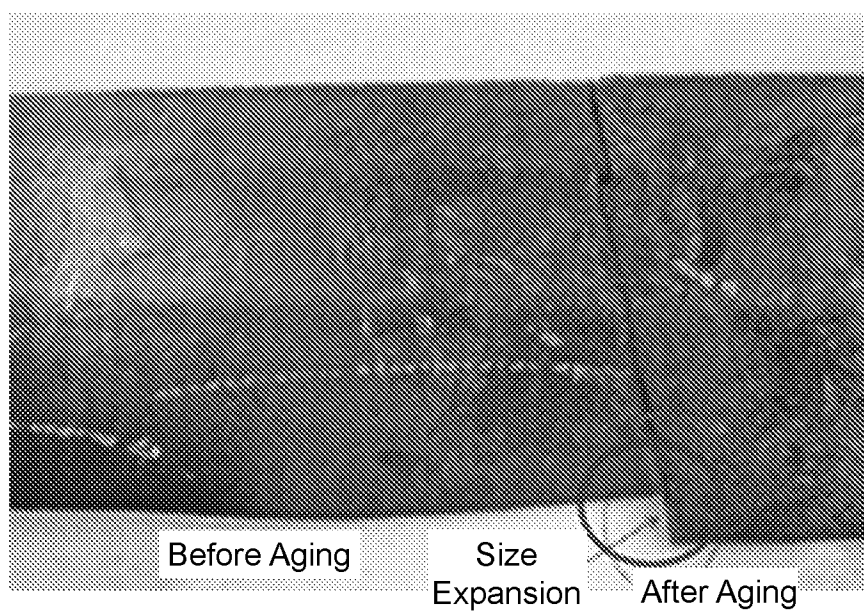
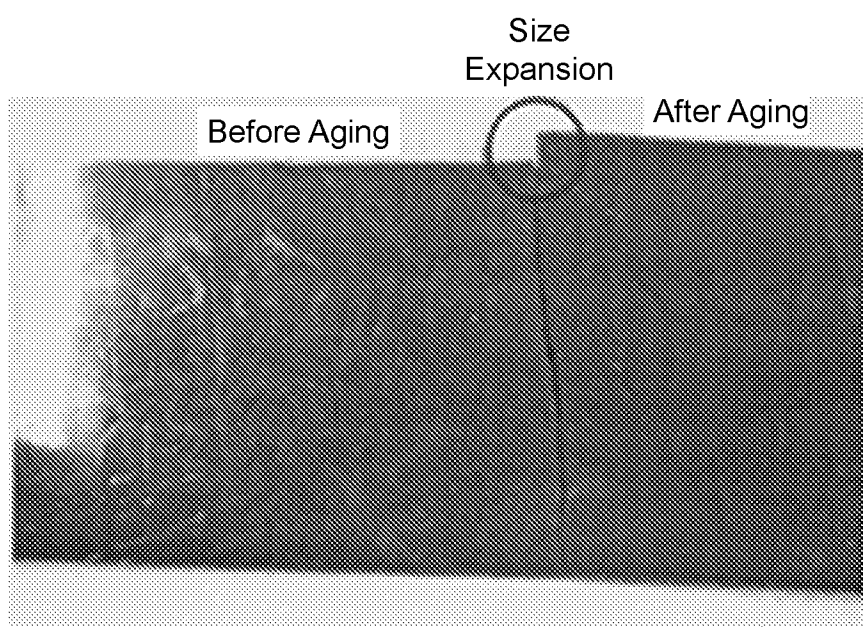


Fig. 14



Fig. 15

*Fig. 16**Fig. 17*

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/025500

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F16K 15/16; F16K 15/14; F16K 47/00; F16K 47/02 (2016.01)

CPC - F16K 15/16; F01L 3/205; F04B 39/1073; F16K 15/144 (2016.05)

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 - F16K 15/14; F16K 15/16; F16K 47/00; F16K 47/02

CPC - F01L 3/205; F04B 39/1073; F16K 15/144; F16K 15/16; Y10T 137/785; Y10T 137/7891; Y10T 137/7892

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

USPC - 137/514; 137/852; 137/855; 137/856; 137/859; 137/904 (keyword delimited)

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

PatBase, Google Patents, Google Scholar, Google

Search terms used: valve, cushion, resilient, elastomer, limit, limiter, stop, stopper, rubber, check, one way, compressor, cushioning, flap, rigid, layer, tongue, reed, graphite

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3,939,867 A (LUNDAVIK et al) 24 February 1976 (24.02.1976) entire document	1-15, 19-29
A	DE 10 2011 009 214 A1 (VOLKSWAGEN AG) 26 July 2012 (26.07.2012) entire document	1-29
A	US 5,327,932 A (ROZEK) 12 July 1994 (12.07.1994) entire document	1-29
A	US 5,884,665 A (THURSTON et al) 23 March 1999 (23.03.1999) entire document	1-29

☐ 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

"E" earlier application or patent but published on or after the international filing date

"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

12 July 2016

Date of mailing of the international search report

08 AUG 2016

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
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PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/025500

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See supplemental page

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-29

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/025500

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-29, are drawn to a valve.

Group II, claims 22-23 and 30-52, are drawn to a material composition.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical features of Group I, a limit element for a one-way valve for limiting the open position of a moving element, a valve plate of a compressor, a valve body with a valve bore that can be closed by the moving element, are not present in Group II; the special technical features of Group II, a material composition and preparation method of grafted graphite comprising graphite particles and grafted groups, comprising copolymer groups of butadiene and acrylonitrile, crosslinking a composition comprising nitrile butadiene rubber are not present in Group I.

Unity exists between claims 1-29 (Group I) or between claims 22-23 and 30-52 (Group II). However unity does not exist between claims (1-21,24-29) and (30-52) since there exists no common special technical feature between independent claims (1,24) and (30,36,44,52) (see PCT Examination Guidelines Chapter 10 at 10.22 Example 2).

Further, Groups I and II share the technical features of an elastomer material. However, these shared technical features do not represent a contribution over the prior art. Specifically, US 5,454,397 A to Miszczak teaches an elastomer material (Abstract regarding reed valve; Fig. 2 regarding reed valve 130, limiter plate 140; Col. 3, Lns. 56-67 regarding limiter plate 140 may be a carbon steel plate and is frequently rubber coated...limiter members 144 limit the range of movement of the reeds 132).

Since none of the special technical features of the Group I and II inventions are found in more than one of the inventions, unity of invention is lacking.