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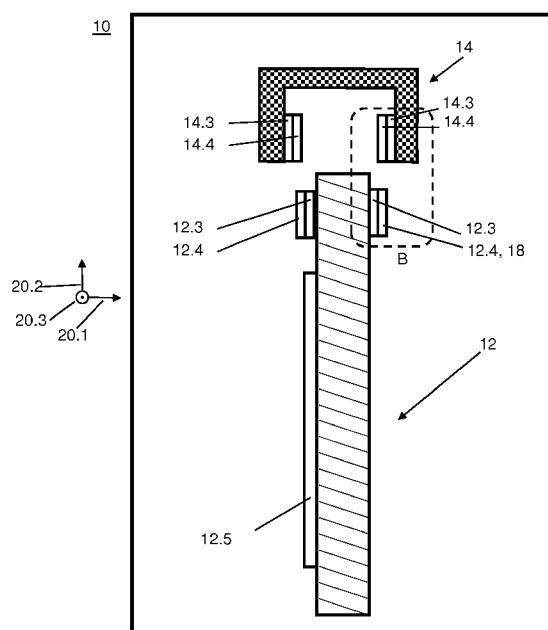


Fig. 1b

(57) Abstract: A magnetic levitation system within a vacuum environment and a method of contactlessly transporting a carrier within a vacuum environment. The system comprises: A carrier that is contactlessly movable in a forward direction; at least one magnetic bearing configured to exert a magnetic force on the carrier in a holding direction opposite to a gravitational force and to contactlessly hold the carrier at the bearing; and a damping device acting on the carrier, the damping device being configured to dampen carrier vibrations in a cross direction that is normal to the forward direction and to the holding direction.

MAGNETIC LEVITATION SYSTEM AND
METHOD OF CONTACTLESSLY TRANSPORTING A CARRIER
WITHIN A VACUUM ENVIRONMENT

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TECHNICAL FIELD

Embodiments of the present disclosure relate to a magnetic levitation system and a method of contactlessly transporting a carrier within a vacuum environment. Embodiments of the present disclosure particularly relate to a magnetic levitation system that is configured to contactlessly hold, position and/or transport a carrier through a vacuum system, wherein the carrier may carry an object such as a substrate, particularly in an essentially vertical orientation. More specifically, the method described herein is adapted to enable damping vibrations of the carrier in a cross direction which is normal to a forward direction in which the carrier is transported and to a holding direction that is opposite to a gravitational force.

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BACKGROUND

A magnetic levitation system can be utilized for the contactless transport of a carrier relative to a base structure, e.g. under sub-atmospheric pressure. An object such as a substrate that is carried by the carrier can be transported from a first position in a vacuum system, i.e. a loading position, to a second position in a vacuum system, e.g. a deposition position. The magnetic levitation systems may allow for a contactless and therefore frictionless transport of the carrier and may reduce the generation of small particles in a vacuum processing system.

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The desired behavior of a magnetic bearing can be compared to a mechanical spring. The larger the distance between attracting magnets, the larger the force attempting to realign the magnets. Since there is no mechanical contact between the magnets, only minor damping effects occur during a relative movement. The mass of the supported and levitating carrier and the spring-like force of the magnets create an almost undamped mechanical oscillation. Typically it takes 20 seconds or more until such vibrations in a typical range of approximately 10, 20 or 30 Hz fade out to a tolerable magnitude.

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At the same time, structures in the micron or even nanometer range sometimes have to be formed on the substrate, so that an extremely precise positioning of the substrate is necessary. Oscillations of the carrier, however, may negatively affect the transport stability and the positioning accuracy of the carrier. Reducing, damping or avoiding oscillations of the carrier of a magnetic levitation system may be challenging. Accordingly, it would be beneficial to improve the transport and positioning accuracy of a magnetic levitation system.

SUMMARY

According to an aspect of the present disclosure, a magnetic levitation system within a vacuum environment is provided. The system includes a carrier that is contactlessly movable in a forward direction, at least one magnetic bearing configured to exert a magnetic force on the carrier in a holding direction opposite to a gravitational force and to contactlessly hold the carrier at the bearing, and a damping device acting on the carrier. The damping device is configured to dampen carrier vibrations in a cross direction that is normal to the forward direction and to the holding direction.

According to another aspect of the present disclosure, a method of contactlessly transporting a carrier within a vacuum environment is provided. The method includes the steps of exerting a magnetic force on the carrier in a holding direction opposite to a gravitational force to contactlessly hold the carrier, moving the carrier in a forward direction, and damping vibrations of the carrier in a cross direction which is normal to the forward direction and the holding direction.

The device and the method of the present disclosure provide an improved magnetic levitation system for holding, positioning and/or moving a carrier within a vacuum environment, and allow for transporting a carrier within a vacuum environment with an improved transport and positioning accuracy of the carrier.

Further aspects, advantages and features of the present disclosure are apparent from the dependent claims, the description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the present disclosure, briefly summarized above, may be had by reference to typical embodiments. The accompanying drawings relate to embodiments of the present disclosure and are described in the following:

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Fig. 1a shows a schematic sectional view of a magnetic levitation system according to embodiments described herein, wherein lateral stabilization is achieved with repellent magnets;

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Fig. 1b shows a schematic sectional view of a magnetic levitation system according to embodiments described herein, wherein vertical and lateral stabilization is achieved with attracting magnets;

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Fig. 2a shows a sectional view of detail B of Fig. 1b, wherein a mobile damping component arranged at the carrier is illustrated, according to embodiments described herein;

Fig. 2b shows a sectional view of the mobile damping component of Fig. 2a that is designed as a dissipating damper, according to embodiments described herein;

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Fig. 2c shows a sectional view of the mobile damping component of Fig. 2a that is designed as a mobile tuned mass damper, according to embodiments described herein;

Fig. 2d shows a sectional view of detail A of Fig. 1a, wherein a mobile damping component arranged at the carrier is illustrated, according to embodiments described herein;

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Fig. 3a shows a sectional view of detail B of Fig. 1b, wherein a stationary damping component arranged at the base is illustrated, according to embodiments described herein;

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Fig. 3b shows a sectional view of the stationary damping component of Fig. 3a that is designed as a dissipating damper, according to embodiments described herein;

Fig. 3d shows a sectional view of detail A of Fig. 1a, wherein a stationary damping component arranged at the base is illustrated, according to embodiments described herein;

Fig. 4a shows a sectional view of detail A of Fig. 1a, wherein a mobile magnetic damper is illustrated, according to embodiments described herein;

Fig. 4b shows a sectional view of detail A of Fig. 1a, wherein a mobile damping component arranged at the carrier and designed as an active damping component is illustrated, according to embodiments described herein;

Fig. 4c shows a sectional view of the mobile damping component arranged at the carrier and designed as an active damping component of Fig. 4b is illustrated, according to embodiments described herein;

Fig. 5a shows a sectional view of detail A of Fig. 1a, wherein a stationary magnetic damper is illustrated, according to embodiments described herein;

Fig. 5b shows a sectional view of the detail A of Fig. 1a, wherein a stationary damping component arranged at the base and designed as an active damping component with a damping actuator moving a guiding rail is illustrated, according to embodiments described herein; and

Fig. 5c shows a sectional view of the detail A of Fig. 1a, wherein a stationary damping component arranged at the base and designed as an active damping component with a damping actuator generating and/or adjusting a laterally oriented magnetic field is illustrated, according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

Reference will now be made in detail to the various embodiments of the present disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to the same components. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation and is not meant as a limitation of the present disclosure. Features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

It is noted here that the terms magnetic levitation or maglev as used within the embodiments described herein can typically be characterized as a concept by which an object is suspended and moved with no support other than magnetic fields. Magnetic force is used to counteract the effect of gravitational force and to move and/or forward the object.

Further, it is noted that in this document the expressions “element X of device Y” and “element X at device Y” or “element X arranged at device Y” are equivalent. Further, the terms “cross” (e.g. cross force, cross vibration), “lateral” and “transversal” are as well equivalent.

Fig. 1a shows a schematic view of an exemplary embodiment of a magnetic levitation (maglev) system 10 within a vacuum environment. Details explained with illustrative reference to Fig. 1a shall not be understood as limited to the elements of Fig. 1a. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

The maglev system 10 as described herein may include:

- A carrier 12 that is contactlessly movable in a forward direction 20.3;
- at least one magnetic bearing 14.2 configured to exert a magnetic force on the carrier 12 in a holding direction 20.2 opposite to a gravitational force and to contactlessly hold the carrier 12 at the bearing 14.2; and
- a damping device 18 acting on the carrier 12, the damping device 18 being configured to dampen carrier vibrations in a cross direction 20.1 that is normal to the forward direction 20.3 and to the holding direction 20.2.

The cross direction 20.1, holding direction 20.2 and forward direction 20.3 can form a coordinate system, especially a Cartesian coordinate system or possibly an inclined coordinate system. For all embodiments, it is clear that the cross direction 20.1 is perpendicular to a planar carrier surface and/or a surface of a planar object 12.5 transported by the carrier 12, which in turn is oriented parallel to the holding direction 20.2.

The carrier 12 may be designed as a plate-like structure and may be configured to carry an object 12.5 such as a planar substrate, mask, shield or waver for the transport of the object

12.5 along a transport path in a vacuum chamber. The carrier 12 may carry the object 12.5 during transport, during alignment with respect to a coating system and/or during deposition on the object 12.5. The carrier 12 or a surface of the carrier 12 may be held and/or transported in in an essentially vertical position and the object 12.5 may be held at the carrier 12 in an essentially vertical orientation during transport and/or deposition. The object 12.5 may be held at the carrier 12 by a mounting device, e.g. a mechanic mount such as a clamp, an electrostatic chuck or a magnetic chuck.

The object 12.5 may be a substrate, particularly a large-area substrate having a size of 0.5 m² or more, more particularly 1 m² or more, or even 5 m² or 10 m² or more. For example, the substrate may be a large-area substrate for display manufacturing.

An organic material may be deposited on the substrate. For example, an OLED device may be manufactured by depositing the organic material on the substrate.

According to embodiments described herein, the damping device 18 may have a housing, inside of which components of the damping device except sensors are arranged. The housing can be vacuum-tight in some embodiments.

The vacuum-tight housing enables an arrangement of the damping unit 18 and the carrier 12 in a vacuum or high vacuum. The vacuum-tight housing is gas-impermeable. Any movements inside the housing, such as movement of a reaction mass 18.9, which may be associated with friction or a vibration, take place only in the inside of the housing, which is hermetically isolated from the outer space.

In this way, it may be possible to use damping materials or material combinations for the damping device 18 that would otherwise be problematic in a vacuum environment or would produce impurities in a vacuum environment.

According to embodiments described herein, the magnetic levitation system 10 may include i) a base 14 for holding, positioning and/or transporting the carrier 12, and/or ii) at least one supporting rail 14.1 arranged at the base 14 vertically spaced from a top side and/or a bottom side of the carrier 12, and/or iii) at least one guiding rail 14.3 arranged at the base 12

laterally spaced from a left side and/or a right side of the carrier 12. In this document, the terms “rail” and “track” are synonymously used.

Herein, top and bottom are positions defined with respect to the holding direction, and
5 left and right are positions defined with respect to the cross direction.

The supporting rail may be designed as a top rail 14.1 that is arranged above the carrier 12, wherein the carrier 12 is held below the top rail 14.1 by the magnetic force. Alternatively or additionally, the supporting rail may be designed as a bottom rail that is arranged below the
10 carrier 12, wherein the carrier 12 is held above the bottom rail by the magnetic force.

According to embodiments described herein, at least one magnetic bearing 14.2 can be arranged at each supporting rail 14.1 and especially each of the magnetic bearings 14.2 may include i) at least one permanent magnet and/or ii) at least one actively controlled
15 electromagnetic bearing actuator 14.5.

A plurality of active magnetic bearings 14.2 may be provided. The magnetic force acts between the base structure 14 and the carrier, such that the carrier 12 is contactlessly held at a predetermined distance from the base 14. In some embodiments, the active magnetic bearing
20 14.2 is configured to generate a magnetic force acting in the holding direction 20.2, which is typically an essentially vertical direction, such that a distance between the top supporting rail 14.1 and the carrier 12 in the holding direction 20.2 can be maintained essentially constant. In particular, at least one active magnetic bearing with a controllable actuator 14.5 may provide an attractive magnetic force between the carrier 12 and the base 14.

According to embodiments described herein, the magnetic levitation system 10 may include at least one vertical magnetic counterpart 12.2 arranged at the top side and/or the bottom side of the carrier 12. The vertical magnetic counterpart 12.2 at the carrier 12 may magnetically interact with the magnetic bearing 14.2 at the base 14, thus exerting a magnetic
30 force on the carrier 12 in the holding direction 20.2 opposite to the gravitational force and contactlessly holding the carrier 12 at the bearing 14.2. Herein, vertical stabilization can be achieved with repellent magnets.

According to embodiments described herein, the magnetic levitation system 10 may include at least one guiding magnet 14.4 that may be arranged at each guiding rail 14.3, wherein particularly the guiding magnet 14.4 includes at least one permanent magnet for providing a side stabilization of the carrier 12 in the cross direction 20.1 and/or at least one
5 actively controlled electromagnetic damping actuator for providing a side damping of the carrier 12 in the cross direction 20.1. The cross direction 20.1 may correspond to an essentially horizontal direction, particularly to a thickness direction of the carrier 12. Herein, lateral stabilization can be achieved with repellent magnets.

10 An actively controlled electromagnetic actuator of a magnetic bearing 14.2, a guiding magnet 14.4 or any other device generating a magnetic field may include an electromagnetic coil or a device based on a mechanism of magnetic repulsion by eddy current, that can each be actively controllable.

15 According to embodiments described herein, the magnetic levitation system 10 may include at least one lateral magnetic counterpart 12.4 arranged at the left side and/or the right side of the carrier 12. Each of the magnetic counterparts may include at least one permanent magnet and/or at least one actively controlled electromagnetic counterpart actuator, such as an electromagnetic coil or a device based on a mechanism of magnetic repulsion by eddy current,
20 thus exerting a magnetic force on the carrier 12 in the cross direction 20.1 and contactlessly maintaining the carrier 12 at a predefined distance from the guiding rail 14.3 and guiding the carrier 12 along the guiding rail 14.3.

The guiding magnet 14.4 may be a passive magnetic stabilizing device. In particular,
25 the guiding magnet 14.4 may include a first plurality of permanent magnets fixed to the base 14 and the lateral magnetic counterpart 12.4 may include a second plurality of permanent magnets fixed to the guiding rail 12.3 at the carrier 12. The repulsive magnetic forces between the first plurality of permanent magnets and the second plurality of permanent magnets may urge the carrier 12 to a predetermined position in the cross direction 20.1, e.g. to a position at
30 a predetermined distance from a guiding rail 14.3 at the base 14 or to a center position between left and right guiding rails 14.3 at the base 14.

For example, a parameter such as an electric current which is applied to the actively controlled electromagnetic bearing actuator 14.5 or to the actively controlled electromagnetic

counterpart actuator may be controlled depending on a parameter such as a distance between the carrier 12 and the base 14. In particular, a distance between the supporting rail 12.1 and/or guiding rail 12.3 and the carrier 12 may be measured by a distance sensor, and the magnetic field strength of the bearing actuator 14.5 may be set depending on the measured distance. In particular, the magnetic field strength may be increased in the case of a distance above a predetermined threshold value, and the magnetic field strength may be decreased in the case of a distance below the threshold value. The actuator may be controlled in a closed loop or feedback control.

According to embodiments described herein, the magnetic levitation system 10 may include at least one mobile damping component 18.1 arranged at the carrier 12 (see Fig. 2a-2c, 4a-4c) or at least one stationary damping component 18.2 arranged at the base 14 and particularly spaced apart from the carrier 12, that especially may be arranged at a guiding rail 14.3 of the base 14 (see Fig. 3a, 3b, 5a, 5b). The stationary damping component 18.2 and the mobile damping component 18.1 can each include a passive damping component 18.3 or an active damping component 18.4.

According to embodiments described herein and with regard to the operation and arrangement of the damping device 18, several embodiments may be provided for damping the lateral vibrations of the carrier 12.

As far as the operation of the damping device 18 is concerned, the damping device 18 may include i) at least one passive damping component 18.3 and/or ii) at least one active damping component 18.4.

As far as the arrangement of the damping device 18 is concerned, the damping device 18 may include a) at least one mobile damping component 18.1 arranged at the carrier 12 and/or b) at least one stationary damping component 18.2 arranged at the base 14 and in particular spaced apart from the carrier 12.

The mobile damping component 18.1 may be arranged at a vertical magnetic counterpart 12.2 of the carrier 12, and/or at a lateral magnetic counterpart 12.4 of the carrier 12, and the stationary damping component 18.2 may be arranged at a supporting rail 14.1 of the base 14, and/or at a guiding rail 14.3 of the base 14.

As illustrated in Fig. 1a, the stationary damping component 18.2 can be fixed at the guiding rail 14.3 at the base 14. The detail marked as “A” in Fig. 1a contains components of the maglev system where the damping device 18 can be arranged in whole or in part. In order to explain the different embodiments of the damping device 18, the detail A is zoomed in on and explained in some figures.

According to embodiments described herein, the active damping component 18.4 may include i) at least one vibration sensor configured to generate a vibration sensor signal representative of carrier vibrations in the cross direction 20.1, and/or ii) at least one damping actuator 18.15, 18.16 configured to generate counter vibrations in response to a damping actuator signal, and/or iii) at least one controller 18.13 connected to the vibration sensor 18.14 and to the damping actuator 18.15, 18.16. The controller 18.13 may be configured to generate the damping actuator signal in response to the vibration sensor signal, in particular such that the counter vibrations damp or attenuate the carrier vibrations in the cross direction 20.1.

According to embodiments described herein, the vibration sensor may include at least one of a position sensor, a velocity sensor, an acceleration sensor, a force sensor, a pressure sensor, a hall sensor.

As illustrated in Fig. 1a, the actuator at the lateral guiding rail 14.3 at the base 14 can be designed to generate a magnetic field of the lateral guiding magnet 14.4 on the base 14 when the guiding magnet 14.4 is flowed through by an actuator current. The magnetic field of the lateral guiding magnet 14.4 on the base 14 can interact with a lateral guiding magnet 12.4 on the carrier 12 to exert a magnetic transverse or cross force on the carrier 12.

The magnetic field and the associated magnetic cross force can be used to counteract the carrier vibrations. Thus, said magnetic field is a magnetic field for lateral damping. The counteracting magnetic force on the carrier 12 can be provided and controlled by a control loop for lateral damping, by adjusting and/or regulating an actuator current.

The dampening magnetic cross force counteracting carrier cross vibrations can be provided by the magnetic field of the lateral guiding magnet 14.4. An oscillating magnetic cross force, particularly with the frequency of the carrier cross vibrations and phase shifted by

90°, interacting with the carrier 12 may achieve a dampening or cancelling effect on the carrier cross vibrations. In the following, several concepts and devices for providing such an oscillating magnetic cross force are described.

5 According to embodiments described herein, a stationary damping actuator 18.16, which is part of an active stationary damping component 18.2, may be configured to adaptively form and/or adjust an interfering of a magnetic field with the carrier 12, in particular of the magnetic field generated by a magnetic guide element and/or an electromagnetic bearing actuator 14.5, thus particularly determining and/or adjusting a
10 magnetic force acting on the carrier 12 in the cross direction 20.1.

 According to embodiments described herein, the stationary damping actuator 18.16 may be adapted to move and/or incline the magnetic guide element or the electromagnetic bearing actuator 14.5 relative to the carrier 12 and/or the base 14, to adaptively form and/or adjust the
15 magnetic field interfering with the carrier 12 in the cross direction 20.1. The stationary damping actuator 18.16 may be adapted to incline and/or oscillate the magnetic field lines relative to the vertical direction, especially by superposing an auxiliary magnetic field exerting a force in the cross direction 20.1 on the carrier 12.

20 Fig. 1b shows a schematic sectional view of a magnetic levitation system according to embodiments described herein, wherein vertical and lateral stabilization is achieved with attracting magnets. Details explained with illustrative reference to Fig. 1b shall not be understood as limited to the elements of Fig. 1b. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

25 According to this design, the guiding magnets 14.4 can exert an attractive force in vertical direction on the carrier 12, i.e. on the guiding magnetic counterpart 12.4 at the carrier 12. The magnets 12.4, 14.4 are counter-pole, resulting in attractive forces between the magnets 12.4, 14.4. In order to achieve vertical stabilization, however, actively controlled
30 electromagnetic bearing actuators 14.5 arranged at the top and bottom of the maglev system can be used. Concerning the horizontal direction, the repelling force of equal-polarity magnets 12.4, 14.4 facing each other has the stabilizing effect of mechanical springs. The arrangements shown in Figs. 1a and 1b for the upper range of lateral respectively horizontal stabilization can also be provided in the lower range of the maglev system.

If, for any given reason, the carrier 12 should move sideways, the guiding magnets 14.4 can exert a lateral force on the carrier 12, i.e. on the guiding magnetic counterpart 12.4 at the carrier 12, which creates and exerts a force in the lateral direction on the carrier 12, which counteracts the evasion. This allows the carrier 12 to be laterally stabilized.

According to embodiments described herein, the magnetic levitation system may include:

- A carrier that is i) contactlessly movable in a forward direction and ii) adapted to hold a planar object;
- at least one magnetic bearing configured to exert a magnetic force on the carrier to contactlessly hold the carrier at the bearing; and
- a damping device acting on the carrier, the damping device being configured to damp carrier vibrations in a cross direction that is normal to the planar object.

According to this arrangement, the carrier can be transported both in vertical and in horizontal planes (in upright and in lying position) in the forward direction, wherein the terms vertical (upright) or horizontal (lying) indicate an orientation of the carrier related to the vertical direction which is parallel to the gravitational force.

According to this arrangement, the magnetic bearing can be configured to exert a magnetic force on the carrier in a holding direction opposite to a remaining magnet force or in a direction which is opposite to magnetic forces in a horizontal direction. If the carrier 12 is horizontally arranged, repellant guiding magnets 14.4, 12.4 can be used to overcompensate gravitational force. Since repellant magnets 14.4, 12.4 could also generate unstable horizontal forces, according to Earnshaw law, such forces may be stabilized in a horizontal direction by an active magnetic bearing 14.2.

According to this arrangement, the damping device can be configured to dampen carrier vibrations in a cross direction that is normal to the forward direction and to the holding direction.

Fig. 2a shows a sectional view of detail B of Fig. 1b, wherein a mobile damping component 18.1 arranged at a lateral magnetic counterpart 12.4 of carrier 12 is illustrated,

particularly between the carrier 12 and the guiding rail 12.3 on the carrier 12. The mobile damping component 18.1 can be designed as an active or passive damping component 18.3 and is located on the lateral side of the carrier 12 facing the right guiding rail 12.3 at the carrier 12. Details explained with illustrative reference to Fig. 2a shall not be understood as limited to the elements of Fig. 2a. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

According to embodiments described herein, a passive damping component 18.3 may include at least one of a mobile or stationary dissipating damper 18.5, a mobile tuned mass damper 18.6, a mobile 18.7 or a stationary 18.8 magnetic damper. Such a passive damping component 18.3 is particularly suitable for a vacuum-tight encapsulation or for embedding into a vacuum-tight housing, which is decoupled, for example, from a controller of the magnetic bearing 14.2.

Fig. 2b shows a sectional view of the mobile damping component 18.1 of Fig. 2a that is designed as a dissipating damper 18.5. The mobile dissipating damper 18.5 may include a reaction mass 18.9 and a dissipating element 18.10, wherein the dissipating element 18.10 is rigidly connected to one side to the reaction mass 18.9 and to the other side to the carrier 12. Especially, no rigid connection exists between the dissipating damper 18.5 and the carrier guiding rail 12.3. Instead, a joint 12.6 may rigidly connect the carrier guiding rail 12.3 and the carrier 12. Details explained with illustrative reference to Fig. 2b shall not be understood as limited to the elements of Fig. 2b. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

An oscillating force is exerted on the dissipation element by the vibrations of the carrier 12 connected to the dissipation element. Due to the rigid connection of the dissipation element to the reaction mass 18.9, which in comparison to the dissipation element has a considerably larger mass and thus a high inertia, the dissipation element cannot vibrate in a free manner but instead it opposes the oscillating force of the carrier 12 with a counterforce.

The superposition of the oscillating force of the carrier 12 and the braking counterforce of the dissipation element results in the energy of the carrier vibrations being consumed, i.e. transformed into heat so that the dissipation element is heated. The vibration amplitude of the

carrier 12 decreases with each oscillation, so that the carrier vibrations subside after a few oscillations.

In this way, the dissipating damper 18.5 provides an efficient cross vibration damping effect at a low price.

Fig. 3a shows a sectional view of detail B of Fig. 1b, wherein a stationary damping component 18.2 arranged at the base 14 is illustrated. The stationary damping component 18.2 can be designed as a passive damping component 18.3 and is located on the lateral side of the base 14 facing the right guiding rail 14.3 at the base 14. Details explained with illustrative reference to Fig. 3a shall not be understood as limited to the elements of Fig. 3a. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

According to embodiments described herein, the stationary dissipating damper 18.5 may include a dissipating element 18.10, wherein the dissipating element 18.10 is rigidly connected to one side to the base 14 and to the other side to a guiding rail 14.3 at the base 14.

Fig. 3b shows a sectional view of the stationary damping component 18.2 of Fig. 3a that is designed as a dissipating damper 18.5. Details explained with illustrative reference to Fig. 3b shall not be understood as limited to the elements of Fig. 3b. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

According to embodiments described herein, the dissipating element 18.10 may include a damping material, such as a rubber compound (e.g. Viton®), a polymer, an elastomer, a damping cushion (e.g. Sylomer ®), a metal foam, a metal sponge (e.g. Stop-Choc®), a viscoelastic material, a viscous fluid, a high damping alloy, or a particle damping material. Such materials may have high stiffness in the vertical direction so that the magnet tracks cannot attract each other, and may have low stiffness in the cross direction 20.1, to allow relative motion for the damping effect of the cross vibrations. An elastomer may also be used for both lateral tracks, in combination.

Said materials are particularly suitable for vacuum applications, are elastic and provide good dampening properties. Accordingly, vibrations of the carrier 12 can effectively be dampened. In order to prevent contamination of the vacuum by the materials, e.g. by residual moisture in the materials, the damping component 18.2 can advantageously be encapsulated or sealed to the outside. Such encapsulation can generally be used for materials that are inappropriate for use in vacuum.

The dissipating element 18.10 may further include a piezoelectric material or a viscoelastic material.

According to embodiments described herein, the dissipating element 18.10 may include a wire rope isolator that is a helical spring consisting of a stranded cable formed into a loop. The remarkable damping effect is the result of the relative friction between the cable's individual strands. In order to prevent contamination of the vacuum by the materials, e. g. by the release of particles due to friction, the damping component 18.2 can advantageously be encapsulated or sealed to the outside.

A piezoelectric material or element can be used both for a passive damping component 18.3 and for an active damping component 18.4.

Passive damping is achieved by applying a resistive shunt to a piezo. This design is very robust with respect to structural uncertainties. In order to obtain high damping values, the piezo may also be shunted with a tuned electrical network, the impedance of which is appropriately matched to the mechanical vibrations.

Active vibration control is realized by regarding the piezoelectric material or element as either sensor or actuator, to be used within a control loop. Herein, two situations can be distinguished: Collocation and non-collocation. Active damping can be realized by means of collocated actuator-sensor-pairs. In case the actuator-sensor-pair can be properly designed within the structure (i.e., with a minimum amount of crosstalk between the actuator and the sensor), excellent damping values can be robustly obtained with a passivity based control law. Further, distributed sensors and actuators, together with MIMO-control can be used.

For active control, it is also possible to use a single piezoelectric element both as sensor and as actuator. Such a configuration may however suffer from crosstalk. High damping values can then be obtained by compensating for the crosstalk, which amounts to shifting the zeros of the control loop.

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A viscoelastic material may achieve an effective damping effect by dissipating mechanical energy into heat when the material undergoes cyclic stress due to polymer chain interactions.

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Fig. 3d shows a sectional view of detail A of Fig. 1a, wherein a stationary damping component 18.2 arranged at the base 14 is illustrated, particularly between the base 12 and the guiding rail 14.3 on the base 14. Details explained with illustrative reference to Fig. 3d shall not be understood as limited to the elements of Fig. 3d. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

15

The design shown here corresponds to the design in Fig. 3a with the difference that the magnets 12.4, 14.4 are of identical poles and arranged next to each other so that they repel each other.

20

Fig. 2c shows a sectional view of the mobile damping component 18.1 of Fig. 2a that is designed as a mobile tuned mass damper 18.6. Details explained with illustrative reference to Fig. 2c shall not be understood as limited to the elements of Fig. 2c. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

25

According to embodiments described herein, the mobile tuned mass damper 18.6 may include a spring element 18.11, a reaction mass 18.9 and a dissipating element 18.10, wherein the spring element 18.11 and the dissipating element 18.10 are arranged in parallel between the reaction mass 18.9 and the carrier 12 and are in particular rigidly connected on one side to the reaction mass 18.9 and on the other side to the carrier 12.

30

The mobile tuned mass damper 18.6 may be attached to the carrier 12 in order to reduce the dynamic response of the carrier 12. The frequency of the damper can be tuned to a particular structural frequency so that when that frequency is excited, the damper will

resonate out of phase with the carrier motion. For carrier vibrations around 12 Hz, the absorber may be tuned to 12 Hz plus/minus 3 Hz. Energy is dissipated by the damper inertia force acting on the carrier 12. Especially, no rigid connection exists between the tuned mass damper 18.6 and the carrier guiding rail 12.3. Instead, a joint 12.6 may rigidly connect the carrier guiding rail 12.3 and the carrier 12.

In other words, the cross vibrations of the levitating carrier 12 supported in the lateral magnetic "spring" occur at well-known and only slightly changing frequencies, the so called eigenfrequencies. They can be estimated by the mass m of the carrier 12 and the stiffness k of the magnetic spring with eigenfrequency = $\sqrt{k / m} / 2 / \pi$. A vibration absorber consisting of a reaction mass 18.9, a mechanical spring and a dissipating element 18.10 (damper) can be tuned to such frequencies as to effectively reduce vibrations.

Therefore, any vibration that may occur in this range can be reliably attenuated via the passive damping component 18.3.

According to embodiments described herein, the magnetic damper may include an electrical conductor 18.12 made of an electrically conductive metal such as aluminium or copper, wherein carrier vibrations in the cross direction 20.1 induce in the electrical conductor 18.12 eddy currents which dampen the carrier vibrations.

Fig. 2d shows a sectional view of detail A of Fig. 1a, wherein a mobile damping component 18.1 arranged at a lateral magnetic counterpart 12.4 of carrier 12 is illustrated, particularly between the carrier 12 and the guiding rail 12.3 on the carrier 12. Details explained with illustrative reference to Fig. 2d shall not be understood as limited to the elements of Fig. 2d. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

The design shown here corresponds to the design in Fig. 2a with the difference that the magnets 12.4, 14.4 are of identical poles and arranged next to each other so that they repel each other.

Figs. 4a and 5a each show a sectional view of detail A of Fig. 1a. In Fig. 4a, a mobile magnetic damper 18.7 is illustrated, wherein the electrical conductor 18.12 is arranged on the

guiding magnetic counterpart 12.4 at the carrier 12. In Fig. 5a, a stationary magnetic damper 18.8 is illustrated, wherein the electrical conductor 18.12 is arranged on the guiding rail 14.3 at the base 14. Details explained with illustrative reference to Fig. 4a, 5a shall not be understood as limited to the elements of Fig. 4a, 5a. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

These embodiments are based on the following technical effect: A relative movement between an electrical conductor 18.12 and a magnetic field 14.6 induces an eddy current in the electrical conductor 18.12. The flow of electrons in the conductor creates an opposing magnetic field which results in damping of the movement and produces heat inside of the conductor similar to heat buildup inside of a power cord during use. The amount of energy transferred to the conductor in the form of heat is equal to the change in kinetic energy lost by the vibration causing the movement – the greater the loss of kinetic energy, the greater the heat buildup in the conductor and the more forceful the damping effect.

According to embodiments described herein, the electrical conductor 18.12 of the mobile magnetic damper 18.7 shown in Fig. 4a can be arranged i) substantially perpendicular or ii) at an angle of at least 45° and/or at most 135° to the magnetic field lines 14.6 of the electromagnetic bearing 14.2. The conductor may be a) a linear conductor 18.12 that extends along a linear axis or b) a coil with at least one loop or winding. The arrangement or angle to the field lines 14.6 is defined in case a) with respect to the conductor axis and in case b) with respect to a coil plane. In particular, the coil plane is perpendicular to a coil axis.

According to embodiments described herein, the electrical conductor 18.12 of the stationary magnetic damper 18.8 shown in Fig. 5a can be arranged i) substantially perpendicular or ii) at an angle of at least 45° and/or at most 135° to the magnetic field lines 14.6 of the guiding magnetic counterpart 12.4 arranged at the carrier 12.

Both arrangements of the electrical conductor 18.12 with respect to the magnetic field lines 14.6 have a significant damping effect on the carrier cross vibrations.

Fig. 5b shows a sectional view of the detail A of Fig. 1a, wherein a stationary damping component 18.2 arranged at the base 14 is illustrated. Details explained with illustrative reference to Fig. 5b shall not be understood as limited to the elements of Fig. 5b. Rather,

those details may also be combined with further embodiments explained with illustrative reference to the other figures.

The stationary damping component 18.2 may include a stationary damping actuator 5 18.16 such as a drive or a servo motor designed to move or displace one of the guiding magnets, depending on and/or adapted to the carrier cross vibrations which can be measured with a vibration or position sensor arranged at the carrier 12 and/or at the base 14.

By using the stationary damping component 18.2 arranged at the base 14 or at the 10 guiding rail 14.3 and shown in Fig. 5b, an oscillating magnetic cross force dampening the carrier cross vibrations can be generated or provided by moving the guiding magnet 14.4 with respect to the guiding rail 14.3 at the base 14, in particular by vibrational movement.

A control loop for cross vibrations dampening may be provided, wherein based on a 15 sensor signal provided by a sensor 18.14 to a drive controller 18.13, a drive current is determined by the controller 18.13 and fed into the drive 18.16, thus determining the drive 18.16 to move the guiding magnet 14.4 in such a way that the magnetic field of the guiding magnet 14.4 and the associated magnetic force acts on the carrier 12 for dampening the carrier cross vibrations, thus forming the control loop. The control loop can be adjusted in such a 20 way that the carrier vibrations fade very quickly.

This results in an effective damping of the cross carrier vibrations, thus considerably improving the transport and positioning accuracy of the magnetic levitation system 10. The described embodiment may be implemented by using the already existing lateral magnets 25 without the need for additional magnets to dampen the lateral vibrations, thus making the implementation cost effective and the operation stable and reliable.

Fig. 5c shows a sectional view of the detail A of Fig. 1a, wherein the stationary damping component 18.2 is arranged at the base 14. Details explained with illustrative 30 reference to Fig. 5c shall not be understood as limited to the elements of Fig. 5c. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

The stationary damping component 18.2 is designed as an active damping component 18.4 with a stationary damping actuator 18.16 generating and/or adjusting a laterally oriented magnetic field. Herein, the following cases may be considered.

5 i) If the guiding magnet 14.4 already includes a controllable magnetic damping actuator, then the stationary damping actuator 18.16 can be integrated in the guiding magnet 14.4 to affect the magnetic field of the guiding magnet 14.4 and can be controlled by an associated control loop. In this case, the active damping component 18.4 may include the control loop for cross vibration damping, and particularly may include only the control loop without the
10 need for a separate magnetic damping actuator.

 ii) Otherwise, the damping actuator 18.16 can be designed as an active magnetic actuator additionally mounted on the lateral guiding rail 14.3 at the base 14 that is controlled by an associated control loop for cross vibration damping. Similarly to case i), the magnetic
15 field generating the dampening cross force acting on the carrier 12 can be determined and/or controlled by the damping actuator current that generates the magnetic field for cross vibration damping.

The stationary damping component 18.2 located on the base 14 can be designed to
20 control the damping actuator current component by means of a corresponding control loop in such a way that the carrier cross vibrations are damped. For this purpose, the carrier cross vibrations can be detected by at least one sensor of the damping device 18, such as a vibration sensor, that is especially mounted on the carrier 12 or on the base 14. Based on a sensor current provided by the sensor to a cross vibrations controller, a damping actuator current is
25 determined by the controller and fed into the lateral guiding magnet 14.4, that generates a magnetic field for dampening the carrier cross vibrations, thus forming a control loop for cross vibrations dampening.

The stationary damping component 18.2 can in both cases advantageously be realized
30 by an electronic circuit that is integrated in the magnetic guiding element. This circumstance is indicated in Fig. 1a by the fact that the guiding magnet 14.4 and the damping device 18 are represented by the very same graphical element.

In case ii), even if the damping actuator 18.16 can be designed as an electromagnetic actuator additionally mounted on the lateral guiding rail 14.3 at the base 14, it is remarkable that the damping actuator 18.16 is specifically designed for damping vibrations having a very small amplitude, especially in the submillimeter or micron range, so that the damping actuator 18.16 can have a small size and a low weight and can consequently be compactly built.

The control loop shown in Fig. 5c works similarly to the control loop of Fig. 5b.

In both cases i) and ii), an effective damping of the cross carrier vibrations is provided, thus considerably improving the transport and positioning accuracy of the magnetic levitation system 10.

The stationary damping component 18.2 can also be arranged at a supporting rail 14.1 of the base 14. The stationary damping component 18.2 may include a magnetic damping actuator for generating an adjustable magnetic field, wherein an adaptively variable and adjustable cross-force can be generated by the magnetic field. In the embodiment that is included in Fig. 1a but is not shown in detail elsewhere, a separate damping actuator arranged at the supporting rail 14.1 or integrated in the bearing 14.2 can be adapted to generate and/or adapt said magnetic field, that may be superimposed on the magnetic field of the magnetic bearing 14.2 and may be generated based on a concept similar to that explained with regard to the embodiments shown in Fig. 5b, 5c.

According to embodiments described herein, a damping actuator, i.e. both a stationary and a mobile damping actuator, may include at least one of a piezoelectric element, a linear drive, a voice coil actuator, and a moving coil actuator.

Fig. 4b shows a sectional view of detail A of Fig. 1a, wherein a mobile damping component 18.1 arranged or fixed at the carrier 12, e.g. between the carrier 12 and the guiding rail 12.3 at the carrier 12, is illustrated. The mobile damping component 18.1 may be designed as an active damping component 18.4. Details explained with illustrative reference to Fig. 4b shall not be understood as limited to the elements of Fig. 4b. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

The active damping component 18.4 may include at least one vibration sensor 18.14 configured to generate a vibration sensor signal representative of carrier vibrations in the cross direction 20.1, a mobile damping actuator 18.15 configured to generate counter vibrations in response to a damping actuator signal, and a controller 18.13 connected to the vibration sensor 18.14 and to the damping actuator 18.15. The controller 18.13 may be configured to generate the damping actuator signal in response to the vibration sensor signal, in particular such that the counter vibrations damp or attenuate the carrier vibrations in the cross direction 20.1.

According to embodiments described herein, a mobile damping actuator 18.5, which is part of the active mobile damping component 18.1, may include a reaction mass 18.9 and a vibrating element 18.17 that is rigidly connected to one side to the reaction mass 18.9 and to the other side to the carrier 12.

Fig. 4c shows a sectional view of the mobile damping component 18.1 arranged at the carrier 12 and designed as an active damping component 18.4 of Fig. 4b is illustrated. Details explained with illustrative reference to Fig. 4c shall not be understood as limited to the elements of Fig. 4c. Rather, those details may also be combined with further embodiments explained with illustrative reference to the other figures.

As already explained, the controller 18.13 of the active mobile damping component 18.1 can determine or adjust a damping actuator current in such a way that the vibrations of the actuator are counter-phase to the vibrations of the carrier 12, so that a superposition of the actuator vibrations and the carrier vibrations causes damping of the carrier vibrations. The vibration amplitude of the carrier 12 decreases with each oscillation, so that the carrier vibrations subside after a few oscillations.

The mobile damping actuator 18.15 can only exert the necessary counterforce acting on the carrier 12 by the rigid connection to the inert reaction mass 18.9. Especially, no rigid connection exists between the mobile damping actuator 18.15 and the carrier guiding rail 12.3. Instead, a joint 12.6 may rigidly connect the carrier guiding rail 12.3 and the carrier 12. The reaction mass 18.9 is typically below 10%, more typically even below 5% of the carrier mass so as to keep the overall weight of the carriers in an acceptable range.

The damping actuator 18.15 of the active mobile damping component 18.1 may include a drive, e.g. a micro motor, or a piezoelectric element. A battery or a wireless energy transfer can be provided for the power supply.

5 As shown in Figs. 1a and 1b, contactlessly transporting a carrier 12 within a vacuum environment includes the steps of:

- Exerting a magnetic force on the carrier 12 in a holding direction 20.2 opposite to a gravitational force to contactlessly hold the carrier 12;
- moving the carrier 12 in a forward direction 20.3; and
- 10 - damping vibrations of the carrier 12 in a cross direction 20.1 which is normal to the forward direction 20.3 and the holding direction 20.2.

Damping the carrier vibrations may be performed a) by passively dissipating the energy of the carrier vibrations or b) by exerting an actively or adaptively controllable magnetic force
15 in the cross direction 20.1 on the carrier 12 and/or by superposing controllable counter vibrations to the carrier vibration, particularly with a frequency of the carrier cross vibrations and phase shifted by 90°.

Moving the carrier 12 may be enabled by exerting a magnetic force on the carrier 12 in
20 the forward direction 20.3.

This written description uses examples to disclose the disclosure, including the best mode, and also to enable any person skilled in the art to practice the described subject-matter, including making and using any apparatus or system and performing any incorporated
25 methods. Embodiments described herein provide an improved method and apparatus for holding, positioning and/or moving a carrier within a vacuum environment, and allow for transporting a carrier within a vacuum environment with an improved transport and positioning accuracy of the carrier. While various specific embodiments have been disclosed in the foregoing, mutually non-exclusive features of the embodiments described above may
30 be combined with each other. The patentable scope is defined by the claims, and other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

CLAIMS

1. A magnetic levitation system within a vacuum environment, comprising:

A carrier that is contactlessly movable in a forward direction;

5 at least one magnetic bearing configured to exert a magnetic force on the carrier in a holding direction opposite to a gravitational force and to contactlessly hold the carrier at the bearing; and

a damping device acting on the carrier, the damping device being configured to damp carrier vibrations in a cross direction that is normal to the forward direction and to the holding
10 direction.

2. The magnetic levitation system according to claim 1, comprising at least one of the following:

A base for holding, positioning and/or transporting the carrier;

15 at least one supporting rail arranged at the base vertically spaced from a top side and/or a bottom side of the carrier, and/or at least one guiding rail arranged at the base laterally spaced from a left side and/or a right side of the carrier, wherein particularly at least one magnetic bearing is arranged at each supporting rail;

at least one guiding magnet that in particular is arranged at each guiding rail, wherein
20 particularly the guiding magnet comprises at least one permanent magnet and/or at least one actively controlled electromagnetic damping actuator;

wherein the magnetic bearing and/or the guiding magnet comprises at least one permanent magnet or at least one actively controlled electromagnetic bearing actuator.

25 3. The magnetic levitation system according to any of claims 1 or 2, further comprising:

at least one vertical magnetic counterpart arranged at the top side and/or the bottom side of the carrier;

at least one lateral magnetic counterpart arranged at the left side and/or the right side of the carrier;

30 wherein each of the magnetic counterparts optionally comprises at least one permanent magnet and/or at least one actively controlled electromagnetic counterpart actuator.

4. The magnetic levitation system according to any of claims 1 to 3, wherein

the damping device comprises i) at least one passive damping component and/or ii) at least one active damping component.

5 5. The magnetic levitation system according to any of claims 1 to 4, according to at least one of the following features:

The damping device comprises i) at least one mobile damping component arranged at the carrier and/or ii) at least one stationary damping component is arranged at the base and in particular spaced apart from the carrier;

10 the mobile damping component is arranged at i) a vertical magnetic counterpart of the carrier, and/or at ii) a lateral magnetic counterpart of the carrier;

the stationary damping component is arranged at a supporting rail of the base, and/or at a guiding rail of the base.

15 6. The magnetic levitation system according to any of claims 1 to 5, comprising at least one of the following features:

The active damping component comprises i) at least one vibration sensor configured to generate a vibration sensor signal representative of carrier vibrations in the cross direction, and/or ii) at least one damping actuator configured to generate counter vibrations in response to a damping actuator signal, and/or iii) at least one controller connected to the vibration
20 sensor and to the damping actuator;

the controller is configured to generate the damping actuator signal in response to the vibration sensor signal, in particular such that the counter vibrations damp or attenuate the carrier vibrations in the cross direction.

25 7. The magnetic levitation system according to any of claims 1 to 6, comprising at least one of the following features:

A stationary damping actuator, which is part of an active stationary damping component, is configured to adaptively form and/or adjust an interference of a magnetic field with the carrier, in particular of the magnetic field generated by a magnetic guide element and/or an electromagnetic bearing actuator, thus particularly determining and/or adjusting a
30 magnetic force acting on the carrier in the cross direction;

the stationary damping actuator is adapted to move or incline the magnetic guide element or the electromagnetic bearing actuator relative to the carrier and/or the base, to

adaptively form and/or adjust the magnetic field interfering with the carrier in the cross direction;

the stationary damping actuator is adapted to incline and/or oscillate the magnetic field lines relative to the vertical direction, especially by superposing an auxiliary magnetic field exerting a force in the cross direction on the carrier.

8. The magnetic levitation system according to any of claims 1 to 7, comprising at least one of the following features:

A mobile damping actuator, which is part of an active mobile damping component, comprises a reaction mass and a vibrating element that is rigidly connected on one side to the reaction mass and on the other side to the carrier;

the damping actuator comprises at least one of a piezoelectric element, a linear drive, a voice coil actuator, and a moving coil actuator;

the vibration sensor comprises at least one of a position sensor, a velocity sensor, and an acceleration sensor.

9. The magnetic levitation system according to any of claims 1 to 8, wherein

the passive damping component comprises at least one of a mobile or stationary dissipating damper, a mobile tuned mass damper, a mobile or stationary magnetic damper.

10. The magnetic levitation system according to any of claims 1 to 9, comprising at least one of the following features:

The mobile dissipating damper comprises a reaction mass and a dissipating element, wherein the dissipating element is rigidly connected to one side to the reaction mass and to the other side to the carrier;

the mobile tuned mass damper comprises a spring element, a reaction mass and a dissipating element, wherein the spring element and the dissipating element are arranged in parallel between the reaction mass and the carrier and are in particular rigidly connected to one side to the reaction mass and to the other side to the carrier;

the stationary dissipating damper comprises a dissipating element, wherein the dissipating element is rigidly connected on one side to the base and on the other side to a guiding rail.

11. The magnetic levitation system according to any of claims 1 to 10,
wherein the dissipating element comprises a damping material or a wire rope isolator.

12. The magnetic levitation system according to any of claims 1 to 11, wherein
5 the damping material comprises at least one of a rubber compound, a polymer, an elastomer, a damping cushion, a metal foam, a metal sponge, a viscoelastic material, a viscous fluid, a piezoelectric material, a high damping alloy, a particle damping material.

13. The magnetic levitation system according to any of claims 1 to 12, comprising at
10 least one of the following features:

The magnetic damper comprises an electrical conductor, wherein carrier vibrations in the cross direction induce in the electrical conductor eddy currents damping the carrier vibrations;

the electrical conductor of a mobile magnetic damper is arranged i) substantially
15 perpendicular or ii) at an angle of at least 45° and/or at most 135° to the magnetic field lines of the electromagnetic bearing;

the electrical conductor of a stationary magnetic damper is arranged i) substantially perpendicular or ii) at an angle of at least 45° and/or at most 135° to the magnetic field lines of the magnetic counterpart arranged at the carrier.

20

14. A method of contactlessly transporting a carrier within a vacuum environment, comprising:

Exerting a magnetic force on the carrier in a holding direction opposite to a gravitational force to contactlessly hold the carrier;

25 moving the carrier in a forward direction; and

damping vibrations of the carrier in a cross direction which is normal to the forward direction and the holding direction.

15. The method of claim 14, comprising at least one of:

30 Damping the carrier vibrations is performed by passively dissipating the energy of the carrier vibrations;

damping the carrier vibrations is performed by exerting an actively or adaptively controllable magnetic force in the cross direction on the carrier and/or by superposing

controllable counter vibrations to the carrier vibration, particularly with a frequency of the carrier cross vibrations and phase shifted by 90° ;

moving the carrier is enabled by exerting a magnetic force on the carrier in the forward direction.

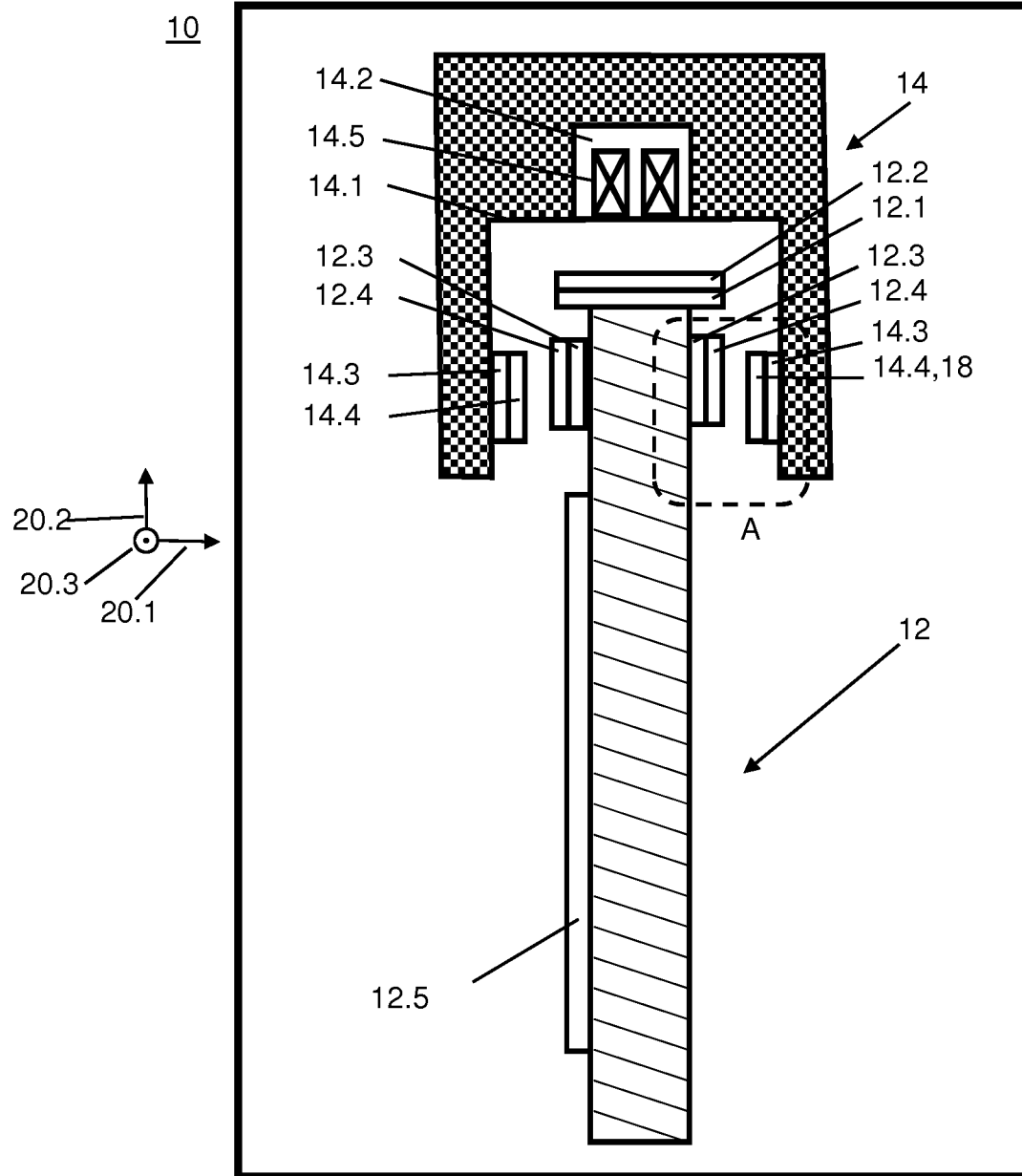


Fig. 1a

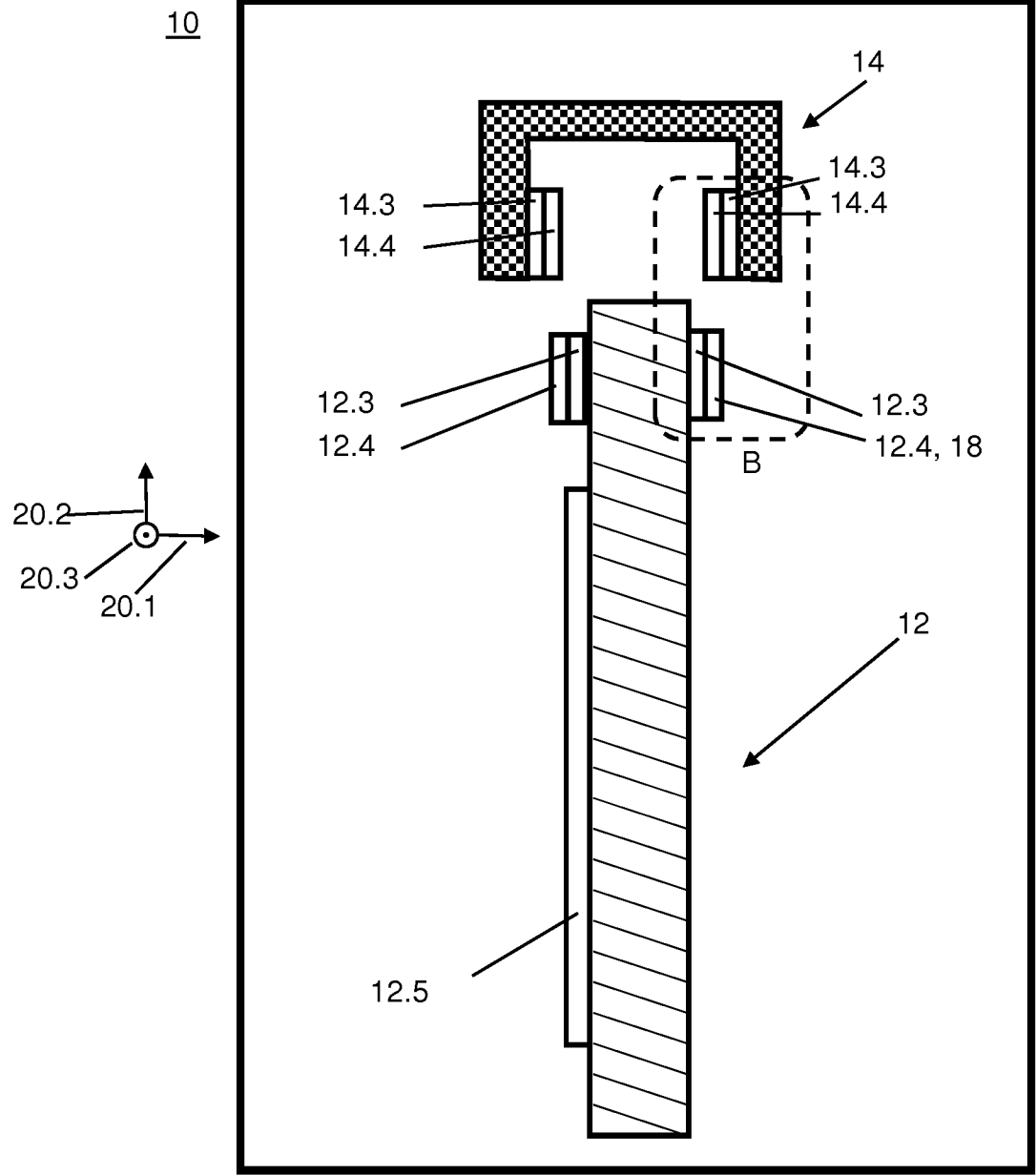


Fig. 1b

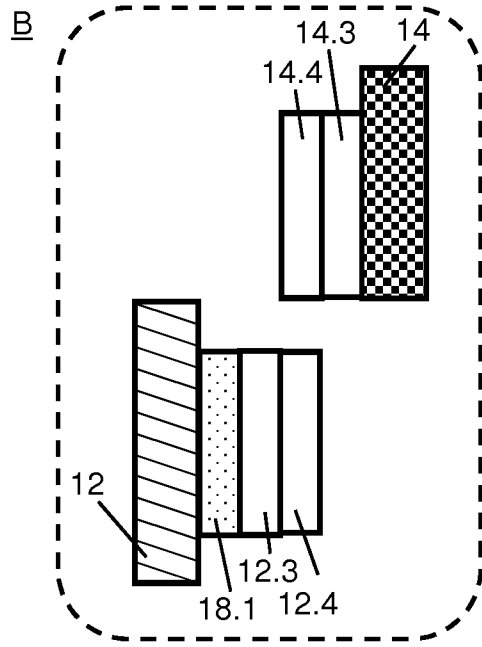


Fig. 2a

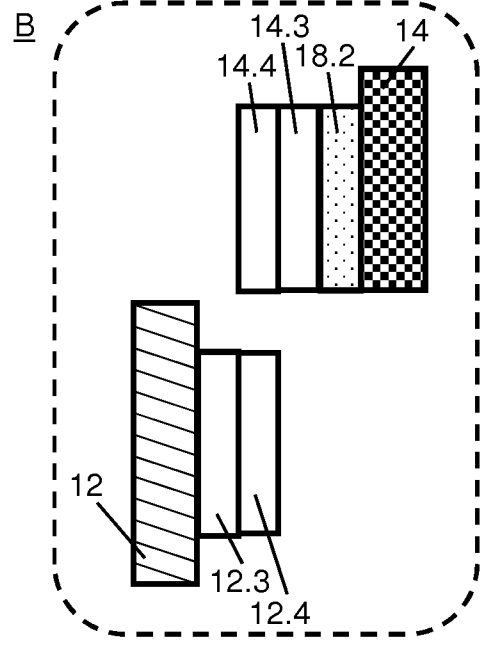


Fig. 3a

18.1 / 18.3

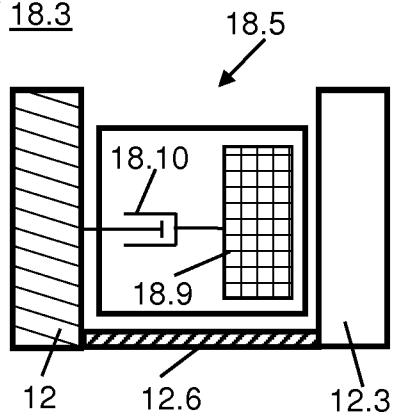


Fig. 2b

18.2 / 18.3

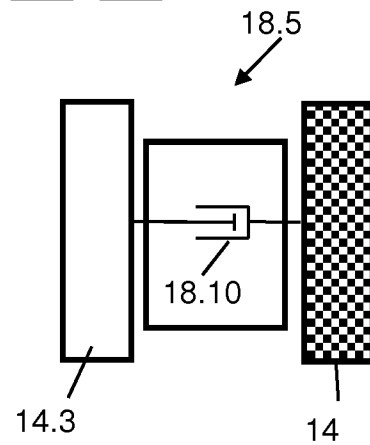


Fig. 3b

18.1 / 18.3

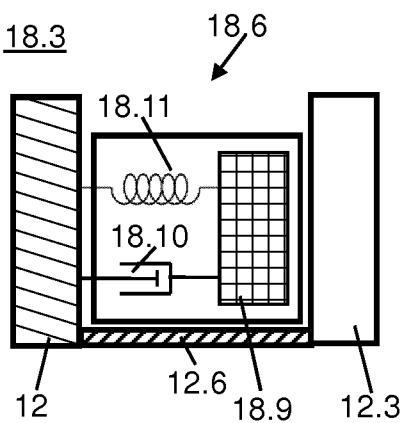


Fig. 2c

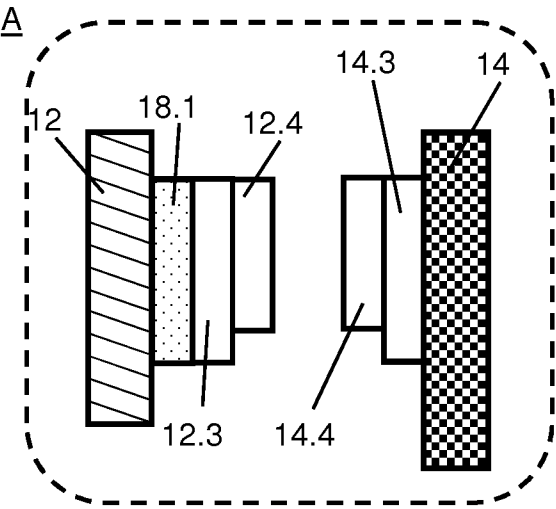


Fig. 2d

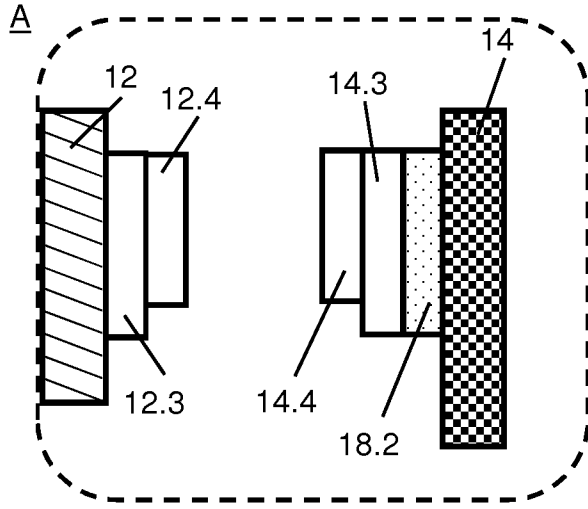


Fig. 3d

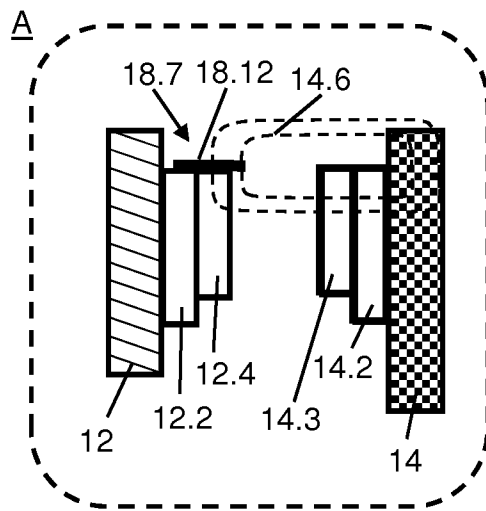


Fig. 4a

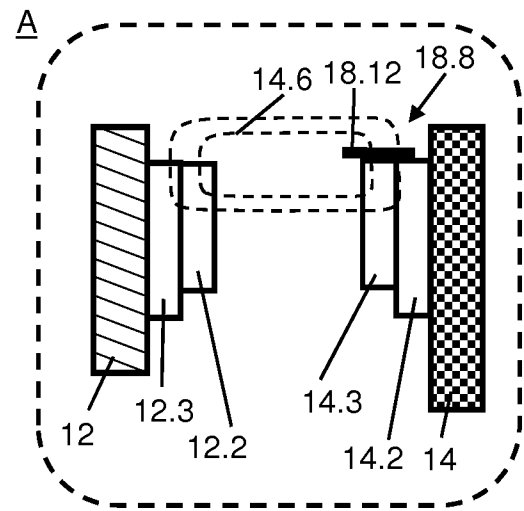


Fig. 5a

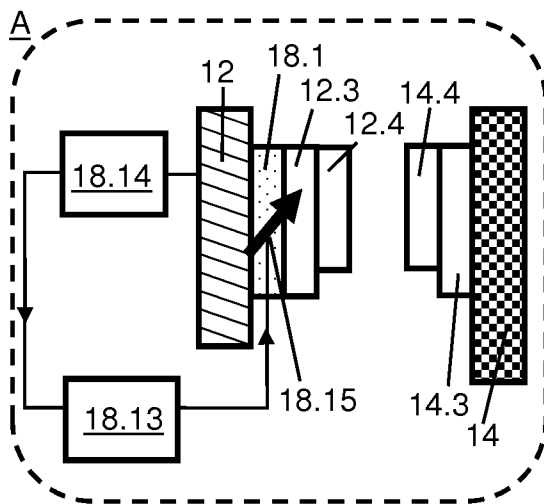


Fig. 4b

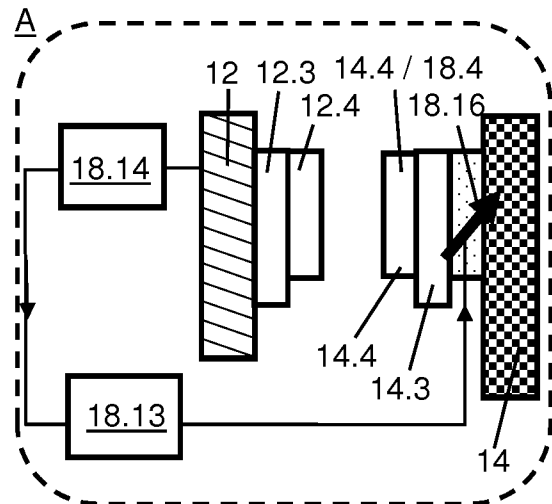


Fig. 5b

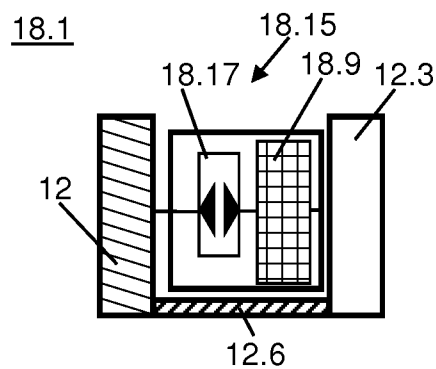


Fig. 4c

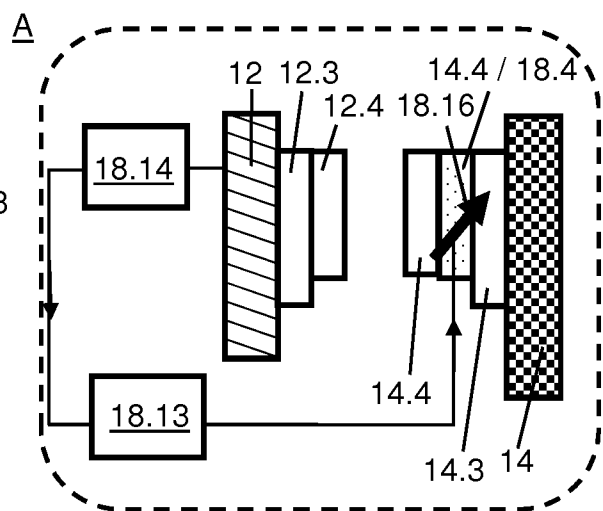


Fig. 5c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/051846

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16F15/00 F16F15/03 F16C32/04
ADD.

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)
F16F F16C

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 107 567 654 A (MECATRONIX AG) 9 January 2018 (2018-01-09)	1-5, 13-15
Y	figures 1,3	6-12
Y	----- US 2009/122284 A1 (BUTLER HANS [NL] ET AL) 14 May 2009 (2009-05-14) figures 2,5 paragraph [0033]	6-12
A	----- KR 2016 0064175 A (MECATRONIX AG [DE]) 7 June 2016 (2016-06-07) the whole document	1-15
A	----- JP S60 36222 A (IRIE KOKEN KK) 25 February 1985 (1985-02-25) the whole document	1-15
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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"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

8 October 2018

Date of mailing of the international search report

17/10/2018

Name and mailing address of the ISA/

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Authorized officer

Thiercelin, A

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/051846

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6 777 833 B1 (WILLIAMS MARK E [US]) 17 August 2004 (2004-08-17) figures 1, 3b -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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