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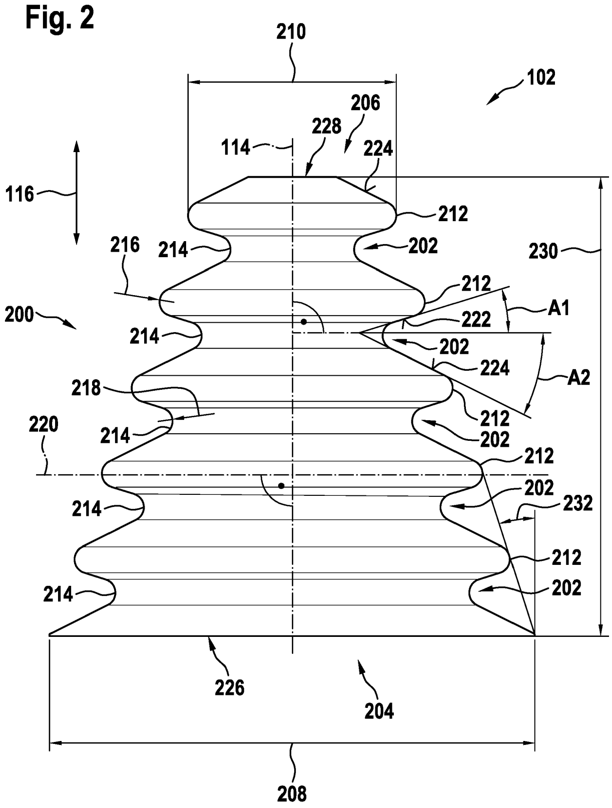
(54) **ENERGY ABSORPTION ELEMENT FOR AN ELEVATOR AND AN ELEVATOR**

(57) The present invention relates to an energy absorption element (102) for an elevator (100), wherein the energy absorption element (102) is shaped as a hollow, frustum shaped, corrugated bellows (200) with an energy absorption direction (116) corresponding to a centerline (114) of the bellows (200), wherein the bellows (200) features folds (202) transverse to the energy absorption direction (116), wherein a ratio between a width (208) of the bellows (200) transverse to the energy absorption direction (116) at a wide end (204) of the bellows (200) and a width (210) of the bellows (200) transverse to the energy absorption direction (116) at a narrow end (206) of the bellows (200) is between two and three.

Fig. 2



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Description

[0001] The present invention relates to an energy absorption element for an elevator and an elevator with such an element.

[0002] In an elevator, an elevator cabin travels vertically inside an elevator shaft. A foundation or pit for the elevator is located at a lower end of this shaft. Springs and/or dampers can be located between a cabin floor of the elevator cabin and the foundation to prevent a hard impact of the cabin on the foundation in case of a malfunction of the elevator. The springs can be spiral springs and/or rubber buffers.

[0003] Impact energy of the impact can also be absorbed by a permanent plastic deformation of an energy absorption element which has to be replaced after absorbing the energy. The energy absorption element can contain box and/or honeycomb structures. Alternatively hydraulic shock absorbers can be placed between the cabin and the foundation.

[0004] There may be a need for an improved energy absorption element for an elevator and an improved elevator.

[0005] Such needs may be met with the subject-matter of the independent claims. Advantageous embodiments are defined in the dependent claims and in the following specification.

[0006] According to a first aspect of the present invention, an energy absorption element for an elevator is submitted. Therein, the energy absorption element is shaped as a hollow, frustum shaped, corrugated bellows with an energy absorption direction corresponding to a centerline of the bellows. The bellows features consecutive protruding and recessed folds transverse to the energy absorption direction, wherein a ratio between a width of the bellows transverse to the energy absorption direction at a wide end of the bellows and a width of the bellows transverse to the energy absorption direction at a narrow end of the bellows is between two and three.

[0007] According to a second aspect of the present invention, an elevator with at last one energy absorption element according to the first aspect of the invention is submitted, wherein the energy absorption element is located between an end face of an elevator shaft of the elevator and an end face of a movable component, particularly an end face of one of a cabin and a counter weight, of the elevator.

[0008] Ideas underlying embodiments of the present invention may be interpreted as being based, inter alia, on the following observations and recognitions.

[0009] An energy absorption element can be placed between two converging objects. The energy absorption element can be referred to as energy absorber or buffer. The energy absorption element is configured to reduce a velocity of a relative motion between the converging objects by absorbing a kinetic energy difference between the converging objects. The energy absorption element can start absorbing energy when it is compressed between two converging faces of the converging objects. The kinetic energy difference is converted into a permanent deformation of the energy absorption element and heat. The energy absorption element generally is not meant for everyday use. Instead, the energy absorption element is meant for emergency use, i.e. for use upon occurrence of any malfunction in the elevator. The energy absorption element can be compressed in an energy absorption direction. The energy absorption direction can coincide with a direction of relative movement between the converging objects. In an elevator the energy absorption direction can coincide with a vertical direction. In an elevator the converging objects can be a fixed element of the elevator and a mobile element of the elevator. The fixed element can be a foundation of the elevator's shaft or a roof of the shaft. The movable element can be the elevator's cabin or a counterweight to the cabin. During normal operation of the elevator, the mobile element is stopped by brakes before it hits the energy absorption element.

[0010] The energy absorption element can be configured to absorb impact energy above a predetermined threshold. Below the threshold the energy absorption element can be elastic and release back to its original shape. The energy absorption element can be configured to undergo a minimal elastic deformation to minimize a resulting rebound force. The amount of absorbed energy per deformed length of the energy absorption element is determined by a geometrical layout or design of the energy absorption element. The amount of absorbed energy at a given moment is largely proportional to an amount of deformed material in that moment.

[0011] The energy absorption element has a narrow end and a wide end. The energy absorption element can be shaped like a cut off cone. The cone can be polygonal or rounded. A polygonal cone can have at least three edges. The more edges the polygonal cone has, the closer it can approximate a rounded shape. The energy absorption element is an empty shell of deformable material. At the narrow end there is less deformable material than at the wide end. Therefore the necessary amount of energy to deform the narrow end is lower than a necessary amount of energy to deform the wide end. The narrow end and the wide end are aligned with the energy absorption direction. The energy to be absorbed is assumed to arrive out of the energy absorption direction. The wide end or the narrow end can face towards the arriving energy. The geometrical layout of the narrow end determines the threshold for the beginning deformation. The amount of absorbed energy per deformed length increases as wider parts of the energy absorption element get deformed consecutively. The wide end will be deformed last. The geometrical layout of the wide end determines the maximum energy absorbable by the formation of the energy absorption element. In other words, the energy absorption element features a progressive absorption ratio. The moving object will be slowed by the absorption of its kinetic energy. The movement will be stopped when the kinetic energy of the object is completely transformed into the deformation.

[0012] The energy absorption element is shaped like a bellows out of corrugated material. The corrugation results in a series of circumferential folds. In a side view, the folds are shaped wavelike. Each fold is arranged in a plane approximately parallel to a plane of the wide end respectively the narrow end of the energy absorption element. Along a way from the narrow end to the wide end each fold is wider than a preceding one. As it takes less energy to deform the folds at the narrow end than to deform the folds at the wide end, the folds at the narrow end will be deformed earlier than the folds at the wide end.

[0013] The energy absorption element has a conical shape with regard to a virtual envelope enclosing its corrugations. The sides of such conical shape of the energy absorption element are slanted with respect to the energy absorption direction. The conical shape prevents buckling transverse to the energy absorption direction. Each fold stabilizes the smaller fold above itself.

[0014] Intense investigations including computer simulations and/or experiments showed that a ratio between the wide end and the narrow end of between two and three may result in a very high buckling resistance. Preferably, the shape of the energy absorption element may be adapted such that the ratio between the wide end and the narrow end is between 2.3 and 2.7 or more preferably at 2.5 ± 0.1. Furthermore, it has been observed that the proposed ratio may result in the energy absorption element having advantageous energy absorption characteristics.

[0015] At least one of the protruding folds and/or recessed folds on the bellows may be rounded. A rounded shape can have a higher deformation resistance than a sharp bend. The material of the energy absorption element is less likely to fail at a rounded fold. Particularly, local peak loads may be prevented within the energy absorption element. By having rounded folds the bellows will generally stay in one piece during deformation.

[0016] At least one ridge of one of the folds may be rounded by a ridge radius of between four and six millimeters. At least one valley of one of the folds may be rounded by a valley radius of between four and six millimeters. During deformation the radius can reduce itself and still stay rounded. A range of four to six millimeters ensures a close succession of the folds on the bellows. An optimized range for the bending radius is reached between four and six millimeters.

[0017] Preferably, the bellows may feature between four to six folds. A number of folds can be determined by dimensions of the bellows. A higher number of folds per given length of the bellows generally results in a lower deformation resistance.

[0018] The folds may feature a short flank and a long flank each. An angle of the short flank relative to a plane perpendicular to the centerline may be smaller than an opposing angle of the long flank. The folds may be asymmetric to a plane of the fold. The asymmetric folds may approximate a saw tooth shaped profile. The different angles of the flanks may lead to a reduced buckling tendency for the bellows.

[0019] The bellows may be rotational symmetric around the centerline. An outline of the bellows may resemble a circular cone. By being rotational symmetric the bellows does not have a preferred evasion direction. The circular cone has the same buckling resistance in all directions.

[0020] The bellows may feature an opening at the narrow end. The bellows may also feature an opening at the wide end. Via the opening an inner volume of the bellows may be connected to the surroundings. The inner volume can be vented through the opening when the energy absorption element is compressed. The opening may be referred to as a hole.

[0021] An angle of the frustum relative to the centerline may be between 5° and 30°, preferably between 11° and 24°. An envelope of the frustum can connect the highest points of all the folds on the bellows. The angle can be measured between the centerline and the envelope. The angle can represent the conical angle of the frustum. Particularly between 11° and 24° the frustum may have the most advantageous buckling resistance.

[0022] A length of the bellows along the centerline may correspond largely to the width of the bellows at the wide end. That way, a ratio between the width at the wide end and the length can be around one. The length may be referred to as height of the bellows. A maximum deformable length of the energy absorption element is slightly shorter than the length of the bellows. The maximum deformable length is generally shorter than the length of the bellows by an accumulated material thickness of the overlapping folds.

[0023] Preferably, the length of the bellows along the centerline may be between 100 millimeters and 500 millimeters, more preferably between 200 millimeters and 300 millimeters. Such dimensions have shown to provide a beneficial compromise between an energy absorption capacity of the energy absorption element and a constructed size required for such energy absorption element, wherein such constructed size should generally be minimized to reduce space requirements in the elevator shaft.

[0024] The bellows may be made with a metal sheet material. The bellows may consists of sheet metal. The bellows may be made up of multiple pieces. The bellows may be made up of a single piece. The bellows may be shaped by hydroforming a tube made out of sheet material. The sheet material may also be rolled and bent.

[0025] A thickness of a sheet material forming the bellows may be between two millimeters and five millimeters preferably between 2.5 millimeters and four millimeters. In this thickness range material properties of the sheet material may be used to full capacity and still be easily formable.

[0026] It shall be noted that possible features and advantages of embodiments of the invention are described herein partly with respect to an energy absorption element and partly with respect to an elevator arrangement comprising such an energy absorption element. One skilled in the art will recognize that the features may be suitably transferred from one embodiment to another and features may be modified, adapted, combined and/or replaced, etc. in order to come to further embodiments of the invention.

[0027] In the following, advantageous embodiments of the invention will be described with reference to the enclosed drawings. However, neither the drawings nor the description shall be interpreted as limiting the invention.

- Figur 1 shows an elevator with at least one energy absorption element according to an embodiment of the invention;
- Figur 2 shows an energy absorption element according to an embodiment of the invention; and
- Figur 3 shows a deformed energy absorption element according to an embodiment of the invention.

[0028] The figures are only schematic and not to scale. Same reference signs refer to same or similar features.

[0029] Fig. 1 shows an elevator 100 with energy absorption elements 102 according to an embodiment of the invention. The elevator 100 features a cabin 104 and a counterweight 106. The cabin 106 and the counterweight 106 are guided in a vertical direction by a rail system 108 of the elevator 100. The cabin 104 and counterweight 106 are connected by at least one suspension traction medium such as a rope or belt. A weight of the cabin 104 and the counterweight 106 is supported by the suspension traction medium. The rail system 108 runs from a lower end of an elevator shaft to an upper end of the shaft. At the lower end the rail system 108 is supported by a foundation 110. At the upper end the rail system 108 supports a drive assembly 112 of the elevator 100. The traction medium runs over pulleys in the drive assembly 112. The weight of the cabin 104 and counterweight 106 is transferred onto the pulleys and a traction force is transmitted into the traction medium. It is to be noted that the arrangement of the elevator 100 as shown in Fig. 1 is only very schematic and exemplary and that an actual arrangement of the elevator 100 may significantly differ from the represented visualization.

[0030] At least one energy absorption element 102 is located between the foundation 110 and the cabin 104. At least another energy absorption element 102 is located between the foundation 110 and the counterweight 106. The energy absorption elements 102 can be fixed to a cabin floor, the counterweight 106 or the foundation 110. The energy absorption elements 102 are designed to damp an impact of the cabin 104 or the counterweight 106 on the foundation 110 respectively. During normal use of the elevator 100 neither the cabin 104 nor the counterweight 106 will impact the energy absorption elements 102. Only in case of a failure e.g. of the drive assembly 112 or the suspension traction medium the cabin 104 and/or the counterweight 106 will compress the energy absorption elements 102.

[0031] In an embodiment at least one energy absorption element 102 is located between the upper end of the shaft and the cabin 104. The energy absorption element 102 may be located on a cabin roof or a ceiling of the shaft. At least another energy absorption element 102 may be located between the shaft's upper end and the counterweight 106. Accordingly this energy absorption element 102 can be located on the ceiling or the counterweight 106.

[0032] The energy absorption elements 102 are frustum shaped and possess a progressive energy absorption characteristics. The energy absorption elements 102 feature a wide side and a narrow side accordingly. A ratio between dimensions of the wide and narrow side is between two and three. A centerline 114 of the energy absorption elements 102 is aligned to a planned energy absorption direction 116 within an angle tolerance. Absolute alignment is not necessary because the frustum shape with the abovementioned dimension ratio prevents bucking transverse to the centerline 114. The energy is absorbed by a permanent plastic deformation of at least one of the energy absorption elements 102 along the centerline 114. For that matter it is irrelevant which side is fixed and which side faces into the shaft. The narrow side will start crumpling as it takes less force to crumple the narrow side than to crumple the wide side.

[0033] Fig. 2 shows an energy absorption element 102 according to an embodiment of the invention. The energy absorption element 102 essentially corresponds to one of the energy absorption elements in Fig. 1. The energy absorption element 102 is shaped as a hollow corrugated bellows 200 out of a sheet material. The material can be metal. The shown bellows 200 features five folds 202 approximately perpendicular to the energy absorption element's 102 energy absorption direction 116. As the bellows 200 is frustum shaped each fold 202 has a different width. The widest fold 202 is located at a wide end 204 of the bellows 200. The narrowest fold 202 is located at a narrow end 206 of the bellows 200. A width 208 of the wide end 204 is proportionate to a width 210 of the narrow end 206 by a ratio between two and three. Here the ratio is 2.5. The different sized folds 202 are regularly spaced and feature about the same step in width to make the energy absorption element 102 frustum shaped. The step in the width can also be irregular so that the envelope of the bellows 200 is curved. The energy absorption direction 116 corresponds approximately to the centerline 114 of the bellows 200 in any way.

[0034] The folds 202 create circumferential ridges 212 and valleys 214 on a surface of the energy absorption element 102. The ridges 212 are rounded by a ridge radius 216. The valleys 214 are rounded by a valley radius 218. In this embodiment the ridge radius 216 is slightly smaller than the valley radius 218.

[0035] In an embodiment the folds 202 are asymmetric to a plane 220 perpendicular to the centerline 114. This way flanks 222 facing the wide end 204 are steeper than flanks 224 facing the narrow end 206. The asymmetric folds 202 have an optimized absorption characteristics. In other words the folds 202 feature a short flank 222 and a long flank 224. An angle A1 of the short flanks 222 relative to the plane 220 is smaller than an angle A2 of the long flanks 224.

[0036] In an embodiment the energy absorption element 102 is open at the wide end 204 and the narrow end 206. A wide opening 226 at the wide end 204 is as wide as the width 208 of the wide end 204. A narrow opening 228 at the narrow end 206 is smaller than the width 210 at the narrow end 206. An additional long flank 224 connects the narrowest ridge and the narrow opening 228. In this embodiment the bellows 200 features five and a half folds 202.

[0037] In an embodiment the energy absorption element 102 is a rotational body. A rotational axis coincides with the centerline 114 or central axis of the bellows 200. For example the bellows 200 can be made by hydroforming a tube.

[0038] Design parameters of the energy absorption element 102 can be adjusted to a required energy absorption. For example the bellows 200 can feature between four and six folds 202. The ridge radius 216 and the valley radius 218 can be varied between four and six millimeters. A length 230 respectively a height 230 of the bellows along the centerline 114 can be varied between 200 and 300 millimeters. An angle 232 of the frustum can vary between 11° and 24°. A material thickness of the bellows 200 can be varied between two and four millimeters. The shown energy absorption element 102 has a width 208 at the wide end 204 of 250 millimeters. The shown energy absorption element 102 has a height 230 of 250 millimeters. The width 210 at the narrow end 206 is 100 millimeters. The material thickness is three millimeters. A resulting strain energy is 56450 kJ.

[0039] In other words Fig. 2 shows a parameter and regression based single piece crumple zone design for elevators. The crumple zone is fabricated from metal sheet. Stainless steel, Mild steel or alloys can be used. The presented design resembles a frustum of cone formed by a corrugated metal sheet or by flaring a hollow metal pipe. A strain energy necessary to deform the crumple zone can be calculated by a polynomial based on the design variables of the crumple zone. This design allows the crumple zone to absorb an appropriate impact energy without going through buckling. The parameter and regression based crumple zone can be sized precisely as per impact requirement. After each impact the crumple zone can be easily replaced.

[0040] As the crumple zone will undergo a nonlinear plastic deformation during an impact, a duration of the impact will increase. This increased impact time will reduce the necessary size of the crumple zone for a given impact energy requirement. Strain energy optimization is used as a criteria to design this crumple zone.

[0041] As the presented crumple zone dissipates the complete impact energy by a permanent deformation, the car is decelerated and comes to a standstill without bouncing back, as with conventional spring buffers. A load factor for a car buffer impact is reduced and less strain is applied on a car buffer plate. Consequently, a size of the buffer plate can be reduced. The reduced load factor also allows a reduction in size for guide rails and brackets.

[0042] Simulations of different designs for the crumple zone provide a unique relationship between the upper and lower diameter of the crumple zone. The simulations established an optimal diameter ratio of approximately 2.5 for a maximum absorption of strain energy without undergoing buckling.

[0043] Sensitivity analysis suggests that the strain energy of the crumple zone is a strong function of sheet thickness and corrugation radius. It's a weak function of diameter if the diameter ratio is maintained at 2.5.

[0044] A polynomial to estimate the strain energy of the crumple zone can be derived by regression analysis. Wide and narrow diameters, sheet thickness, corrugated radius and height of the crumple zone are the design variables for the crumple zone. The ratio between the wide diameter and the narrow diameter is maintained at 2.5.

[0045] Fig. 3 shows a deformed energy absorption element 102 according to an embodiment of the invention. The energy absorption element 102 essentially corresponds to one of the energy absorption elements in Fig. 2. The deformation has started at the narrowest fold 202. At the narrowest fold the flanks 222, 224 almost touch after the deformation. The valley 214 between the two neighboring ridges 212 is essentially closed.

[0046] The impact energy in the shown example was too small to substantially compress the second fold 202. The valley 214 of the second smallest fold 202 is slightly narrower and the ridge radius 216 of the second smallest ridge 212 got smaller. The rest of the folds 202 are essentially unchanged by the impact.

[0047] Finally, it should be noted that the term "comprising" does not exclude other elements or steps and the "a" or "an" does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

Claims

1. Energy absorption element (102) for an elevator (100), wherein the energy absorption element (102) is shaped as a hollow, frustum shaped, corrugated bellows (200) with an energy absorption direction (116) corresponding to a centerline (114) of the bellows (200), wherein the bellows (200) features folds (202) transverse to the energy absorption direction (116), wherein a ratio between a width (208) of the

bellows (200) transverse to the energy absorption direction (116) at a wide end (204) of the bellows (200) and a width (210) of the bellows (200) transverse to the energy absorption direction (116) at a narrow end (206) of the bellows (200) is between two and three.

2. Energy absorption element (102) according to claim 1, wherein at least one of the folds (202) on the bellows (200) is rounded.

3. Energy absorption element (102) according to claim 2, wherein at least one ridge (212) of one of the folds (212) is rounded by a ridge radius (216) of between four and six millimeters.

4. Energy absorption element according to one of the claims 2 to 3, wherein at least one valley (214) of one of the folds (202) is rounded by a valley radius (218) of between four and six millimeters.

5. Energy absorption element (102) according to one of the preceding claims, wherein the bellows (200) features between four and six folds (202).

6. Energy absorption element (102) according to one of the preceding claims, wherein the folds (202) feature a short flank (222) and a long flank (224) each, wherein an angle (A1) of the short flank (222) relative to a plane (220) perpendicular to the centerline (114) is smaller than an opposing angle (A2) of the long flank (224).

7. Energy absorption element (102) according to one of the preceding claims, wherein the bellows (200) is rotational symmetric around the centerline (114).

8. Energy absorption element (102) according to one of the preceding claims, wherein the bellows (200) has an opening (228) at the narrow end (206).

9. Energy absorption element (102) according to one of the preceding claims, wherein an angle (232) of the frustum relative to the centerline (114) is between 5° and 30°.

10. Energy absorption element (102) according to one of the preceding claims, wherein a length (230) of the bellows (200) along the centerline (114) corresponds largely to the width (208) of the bellows (200) at the wide end (204).

11. Energy absorption element (102) according to one of the preceding claims, wherein a length (230) of the bellows (200) along the centerline (114) is between 100 millimeters and 500 millimeters.

12. Energy absorption element (102) according to one of the preceding claims, wherein the bellows (200) is made with a metal sheet material.

13. Energy absorption element (102) according to one of the preceding claims, wherein a thickness of a sheet material forming the bellows (200) is between two millimeters and five millimeters, preferably between 2.5 millimeters and four millimeters.

14. Elevator (100) with at last one energy absorption element (102) according to one of the preceding claims, wherein the energy absorption element (102) is located between an end face of an elevator shaft of the elevator (100) and an end face of a movable component, particularly an end face of one of a cabin (104) and a counter weight (106), of the elevator (100).

Fig. 1

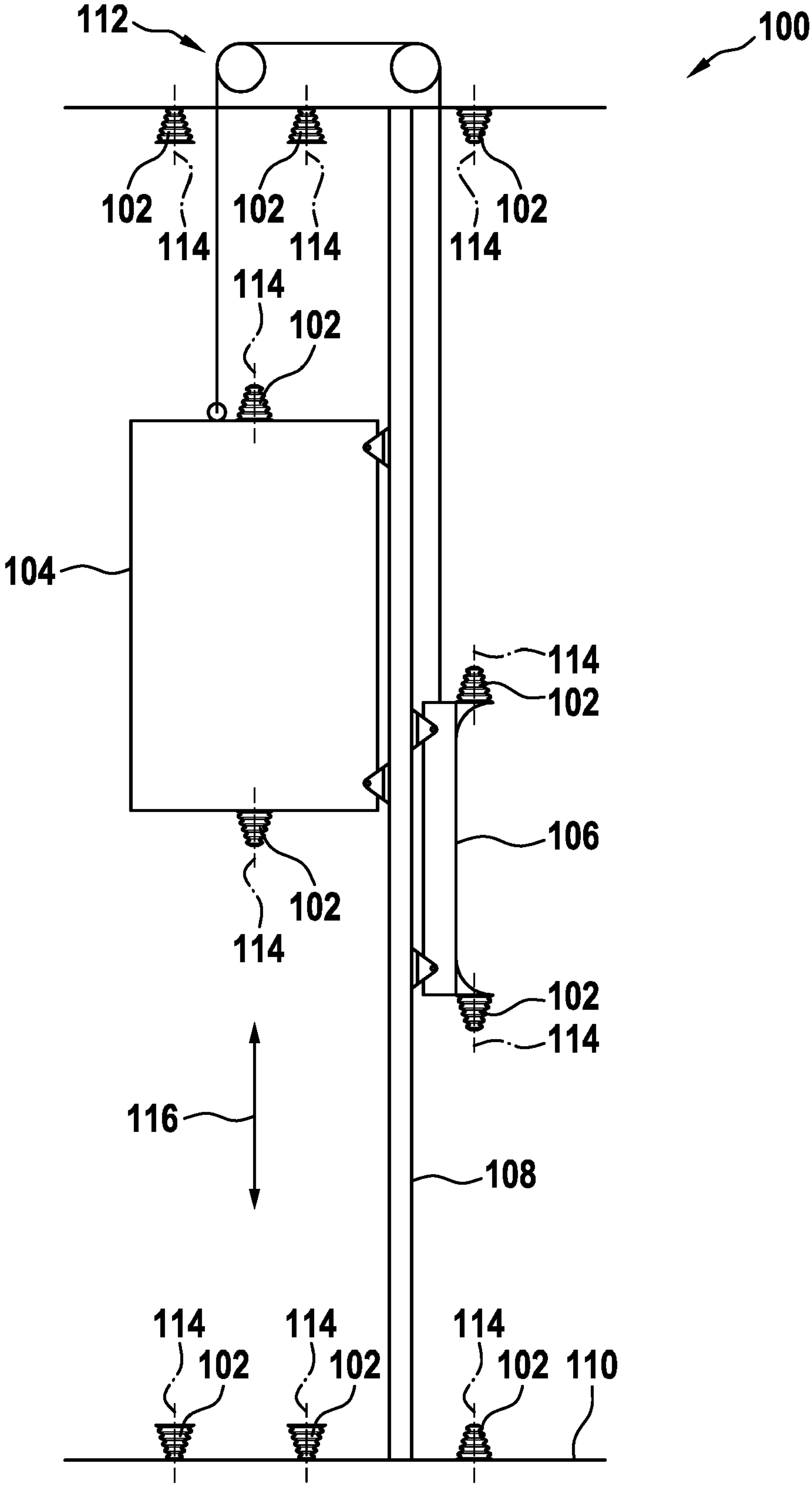
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Fig. 2

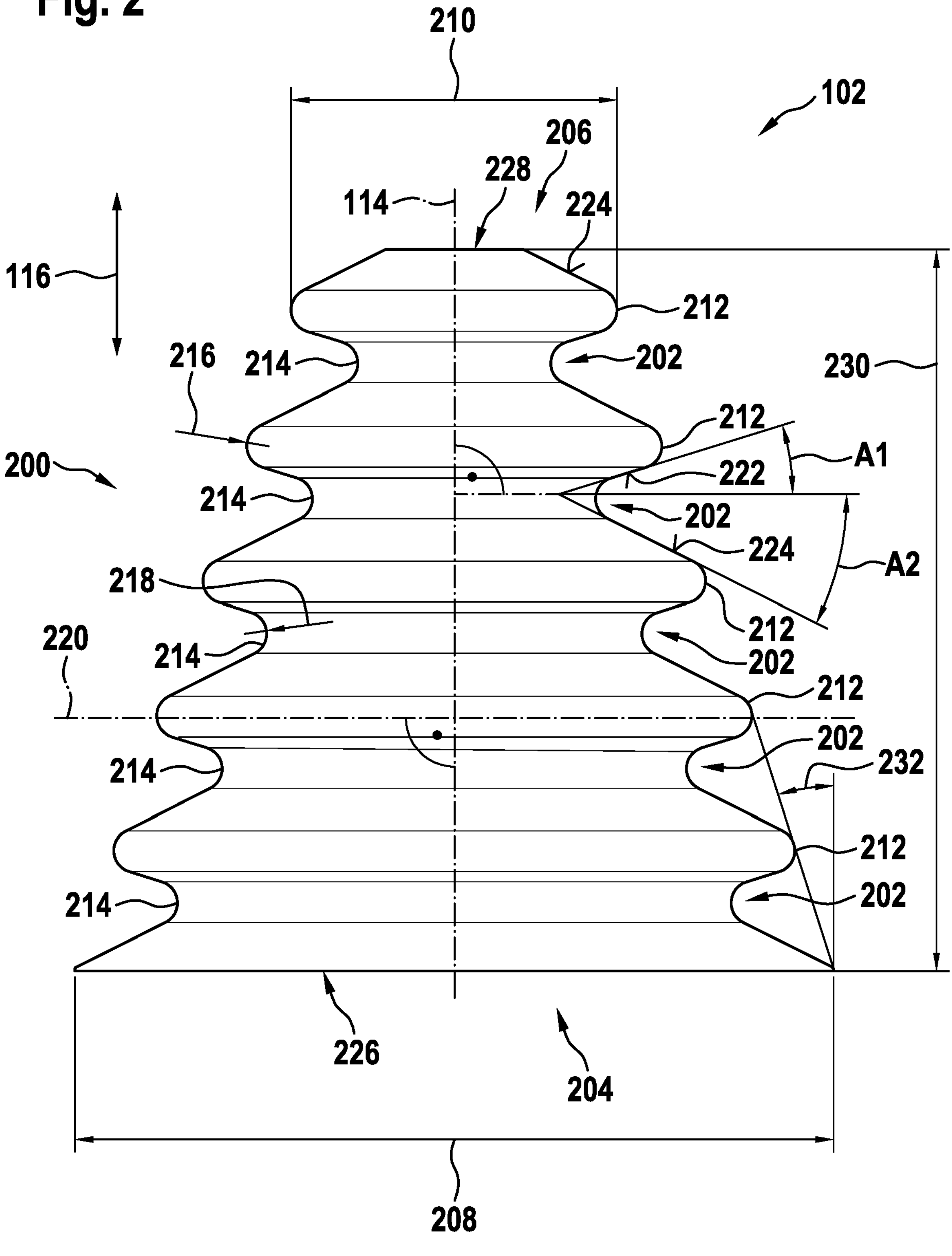
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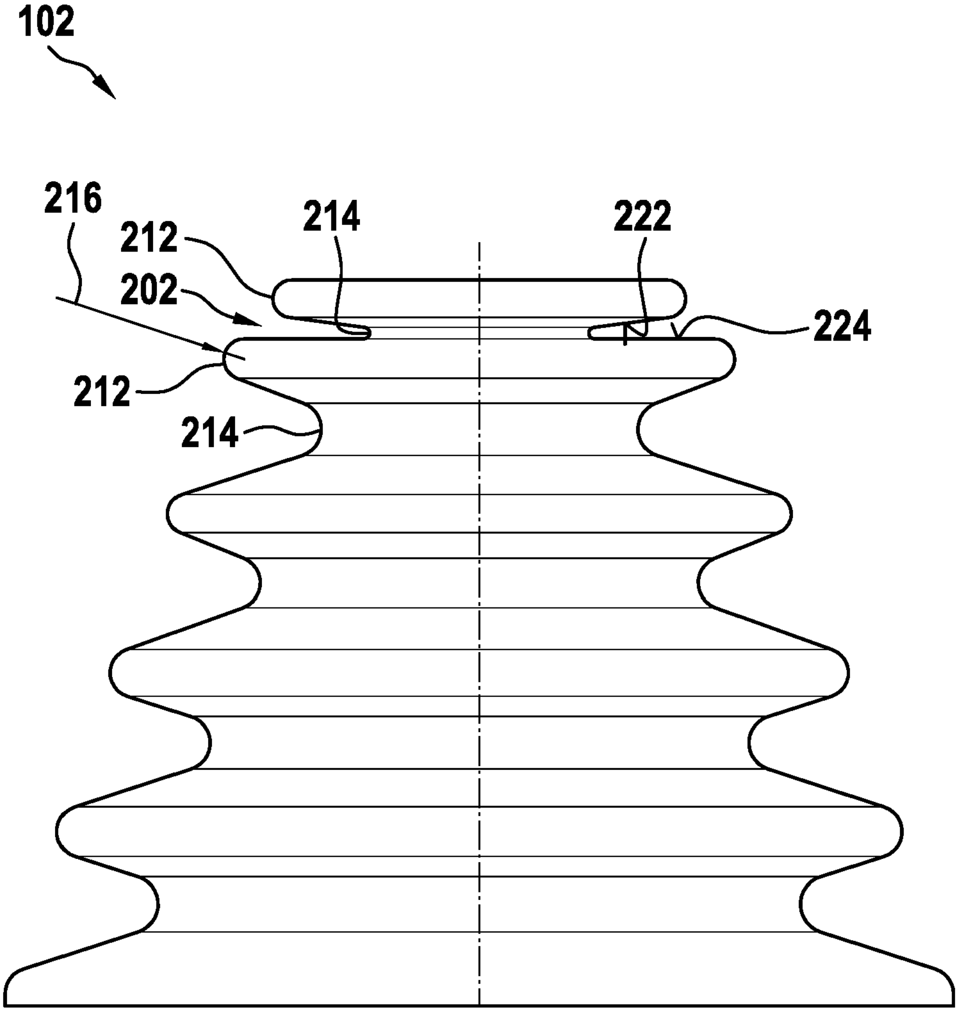
Fig. 3



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EUROPEAN SEARCH REPORT

Application Number
EP 19 21 6996

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	ALIREZA AHMADI ET AL: "Efficient crushable corrugated conical tubes for energy absorption considering axial and oblique loading", PROCEEDINGS OF THE INSTITUTION OF MECHANICAL ENGINEERS. PART C,JOURNAL OF MECHANICAL ENGINEERING SCIENCE, vol. 233, no. 11, 7 June 2019 (2019-06-07), pages 3917-3935, XP055705750, GB ISSN: 0954-4062, DOI: 10.1177/0954406218806006 * pages 1-3 * -----	1-13 14	INV. B66B5/28
X Y	ALKHATIB SAMI E ET AL: "Collapse behavior of thin-walled corrugated tapered tubes", ENGINEERING STRUCTURES, ELSEVIER, AMSTERDAM, NL, vol. 150, 4 August 2017 (2017-08-04), pages 674-692, XP085195503, ISSN: 0141-0296, DOI: 10.1016/J.ENGSTRUCT.2017.07.081 * abstract * * Sections 2.2; 2.3 * * figure 2; tables 1, 5-8 * -----	1-13 14	
Y	JP 2003 192250 A (HITACHI LTD; HITACHI MITO ENG KK) 9 July 2003 (2003-07-09) * abstract; figures 1-8 * -----	14	TECHNICAL FIELDS SEARCHED (IPC) B66B B61K B61G B60R
Y	JP 2002 317845 A (HITACHI LTD) 31 October 2002 (2002-10-31) * abstract; figures 1-14 * -----	14	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	18 June 2020	Bleys, Philip

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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18-06-2020

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82