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(12) # EUROPEAN PATENT APPLICATION

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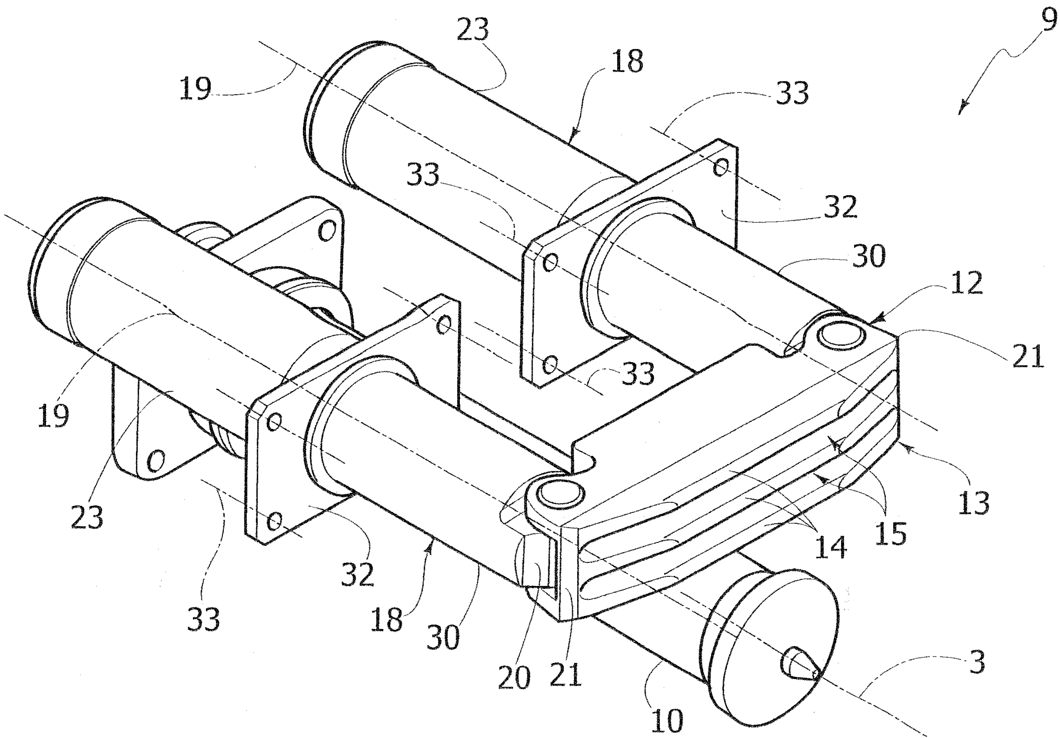
(54) **Train equipped with interfaces that absorb energy between the carriage in case of collision**

(57) A train (1) is equipped with a plurality of carriages (2) and interfaces (8) between the carriages (2), each interface (8) having plastically deformable portions (23,30) that plastically deform when a longitudinal compression load exceeds a preset threshold (B) and, during plastic deformation, provide resistance to longitudinal compression, the mean progression of which includes at least an initial stage where it grows as the longitudinal crushing increases; preferably, this mean progression increases linearly up to a maximum longitudinal crushing (D) of the plastically deformable portions (23,30).

FIG. 3



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Description

[0001] The present invention concerns a train equipped with interfaces that absorb energy between the carriages in case of collision. In particular, the disclosure herein makes reference to a high-speed train, but without any loss in generality.

[0002] As is known, the locomotive of a high-speed train is equipped with front structures that absorb energy by plastically deforming themselves in case of head-on collision. To absorb the impact energy that tends to be transmitted from the locomotive to the following carriages, it is known to provide for interface structures that are plastically deformable, such as the structures described in international patent application WO2005/023618 for example, between the carriages.

[0003] Solutions of the known type are not very satisfactory, as the energy tends to be discharged almost entirely on the interfaces between the first carriages close to the end of the train involved in the collision: thus, the load-carrying chassis or bodies of the first carriages also sustain serious damage, with consequent damage to property and injury to the people transported.

[0004] Therefore, the need is felt to spread the absorption of impact energy along the entire train in an optimal manner.

[0005] To fulfil this need, European patent application EP1477381A1 describes a train in which the load or compression resistance between the carriages placed in the middle is less than the load between the carriages placed at the front and at the rear. However, this solution is unsatisfactory, as the interfaces between the various pairs of carriages must be different from each other along the entire train and, in consequence, must be designed and manufactured in a dedicated manner.

[0006] The object of the present invention is that of embodying a train equipped with interfaces that absorb energy between the carriages in case of collision, which allows the above-described problems to be resolved in a simple and economic manner.

[0007] According to the present invention, a train is embodied that comprises:

- a plurality of carriages, in line and coupled together in a longitudinal direction, and
- an associated interface, between each pair of adjacent carriages, comprising plastically deformable portions that plastically deform when a longitudinal compression load exceeds a preset threshold,

characterized in that, in each interface, during plastic deformation said plastically deformable portions provide resistance to longitudinal compression, the mean progression of which has at least an initial stage where it grows as the longitudinal crushing of said plastically deformable portions increases.

[0008] The invention shall now be described with reference to the enclosed drawings, which illustrate a non-limitative embodiment, where:

- Figure 1 is a partial side view of a preferred embodiment of a train equipped with interfaces that absorb energy between the carriages in case of collision, according to the present invention,
- Figure 2 is similar to Figure 1 and shows the position of the two carriages of the train after a collision,
- Figure 3 shows a detail of Figure 1 on a larger-scale and in perspective,
- Figure 4 is a side view of the detail in Figure 3, with parts of a carriage shown in section, and
- Figure 5 is a graph regarding the detail in Figures 3 and 4.

[0009] In Figure 1, reference numeral 1 indicates, in its entirety, a train defined as a so-called "high-speed" train. In the described example, the train 1 is composed of eight carriages 2 (only two of which are shown), in line and coupled together in a longitudinal direction 3: the two carriages placed at the front and at the rear are powered and equipped with a cab, four intermediate carriages are drawn and two intermediate carriages are powered and positioned between the drawn ones.

[0010] Regarding passive safety in case of collision, the train 1 is designed to meet the directives imposed by the TSI European regulations of 2002, without evident plastic deformation of either the cabs or any of the passenger compartments 4, including the end zones of each carriage 2, where the vestibules and the access zones to the compartments 4 are located.

[0011] To guarantee safety of the compartments 4 during a possible head-on or rear-end collision, an associated safety structure or interface 8 is inserted between each pair of adjacent carriages 2, which is able to absorb energy and, in particular, is constituted by two semi-structures 9, respectively coupled to the bodies or load-carrying chassis 7 of the two adjacent carriages 2.

[0012] The two semi-structures 9 are placed above a bar 10 that connects the carriages 2 together, transmits the tractive forces when in motion, and is associated with two end hinges 11 (of which only one is shown in Figure 4) that allow a change in direction of each carriage 2 with respect to the following one in curves. The two semi-structures 9 are longitudinally spaced apart from each other when in motion, for example, at a distance F of approximately 70 mm, and are substantially equal and symmetrical with respect to an ideal median plane orthogonal to direction 3.

[0013] With reference to Figures 3 and 4, the two semi-structures 9 comprise respective anti-climber members 12, which are substantially rigid, comprising respective boxed rear portions and have respective front surfaces 13 that face each other and are fitted with horizontal ribs 14 defining a plurality of grooves 15 between them.

[0014] The two semi-structures 9 also comprise respective pairs of buffers 18 that extend along respective axes 19 parallel to direction 3, are equal and symmetrical to each other with respect to an ideal vertical plane upon which direction 3 lies.

[0015] The two buffers 18 of each semi-structure 9 terminate, at one axial end, with the respective portions 20 coupled to the lateral ends 21 of member 12: in particular, the portions 20 are hinged at the ends 21 around respective vertical axes. At the opposite axial end, the two buffers 18 terminate with respective hollow cylindrical portions 23, which are housed in fixed positions, in respective axial seats 24 (Figure 4) defined by the body 7. In particular, each seat 24 is defined by two plates 27 and 28, which lie on planes orthogonal to axis 19, are axially spaced apart from each other and are reinforced in a manner not shown.

[0016] The two buffers 18 comprise respective cylindrical portions 30, which extend along axes 19 outside of the associated body 7 between portions 20 and portions 23 and have a smaller diameter that portions 23, and respective outer flanges 32 (Figure 3) that lie on an plane orthogonal to axes 19, are fitted in fixed positions on portions 23 and are fixed to the body 7 by screws (the axis of which is indicated by reference numeral 33) to lock the semi-structure 9.

[0017] With reference to Figure 2 and the graph in Figure 5, in case of collision the devices (not shown) that connect the bar 10 to the bodies 7 break when the compression load (curve segment (a) in Figure 5) exceeds a threshold A, for example, equal to $1.7 * 10^6$ [N], in the direction parallel to direction 3. In this situation, the bar 10 is free to slide with respect to at least one of the two carriages 2, which therefore start to move closer together, reducing distance F to zero. At this point, the grooves 15 of a member 12 are engaged by the ribs 14 of the facing member 12: the engagement between the grooves 15 and the ribs 14 of the two members 12 prevents either of the two carriages 2 from being lifted up with respect to the other.

[0018] When members 12 make contact, the compression load between the two semi-structures 9 in a direction parallel to direction 3 rises rapidly (curve segment indicated by (b) in Figure 5) until a threshold B (for example, $1.6 * 10^6$ [N]) is exceeded, beyond which portions 30 start to move back inside portions 23, causing plastic deformation that absorbs energy. In particular, the plastic deformation or longitudinal crushing stroke of the semi-structure 9 reaches a maximum value C, defined by internal end stops (not shown) that stop portions 30 moving further back into portions 23 along axes 19.

[0019] According to the invention, in each interface 8, the plastically deformable portions (namely portions 23 and 30) offer compression resistance, the mean progression of which has an initial stage where it grows as the plastic deformation stroke increases in a direction parallel to direction 3. In particular, the internal structural and dimensional characteristics (not shown) of the plastically deformable portions are such as to provide each interface 8 with a compression resistance that has a mean progression that grows in a monotonic manner up to a maximum crushing value D, according to a theoretical straight line set by design:

$$Y = ((E - B) / D) * X + B$$

where

X = crushing or plastic deformation stroke in the longitudinal direction of the plastically deformable portions (abscissa X = 0 corresponds to the start of plastic deformation),

Y = longitudinal compression resistance between the bodies 7 of the two adjacent carriages 2 during plastic deformation,

B = longitudinal compression resistance at the start of plastic deformation,

E = longitudinal compression resistance when the maximum crushing value D is reached, and

D = maximum crushing value of the plastically deformable portions of the interface 8.

[0020] The following values (with a maximum permitted variance of 7.5%) could be applicable to the train 1:

$B = 1.6 * 10^6$ [N]
$E = 2.7 * 10^6$ [N]
D = 610 [mm].

[0021] Instead, in the case of a train defined as an underground train, the following values could be applicable (with a maximum permitted variance of 5%):

$B = 0.5 * 10^6$ [N]
$E = 1.0 * 10^6$ [N]
D = 400 [mm].

[0022] As the semi-structures 9 are symmetrical and equal, a similar theoretical straight line, set by design, applies to each semi-structure 9:

$$Y = ((E - B) / C) * X + B$$

where C = (D / 2). A valid theoretical straight line for a semi-structure 9 is indicated by way of example with reference letter (c) in Figure 5.

[0023] It is possible to carry out a test, which can be established by experimental testing or, more easily, by simulation of a collision at a certain speed via appropriate software, to obtain the effective response curve of compression resistance in a longitudinal direction during the plastic deformation of each interface 8 and/or of each semi-structure 9.

[0024] In the case of a quasi-static test, that is with extremely low deformation speeds, the effective response curve is found to be substantially a straight line that is very close, if not identical, to the theoretical line set by design. In the case of a dynamic test, that is with deformation speeds that correspond to those actually encountered in case of collision, the effective response curve normally has fluctuations: by way of example, in Figure 5, reference letter (d) indicates an effective response curve for a semi-structure 9 of the train 1 in case of collision at a speed of 15 [km/h] (the maximum crushing at the end of the test is approximately 80 mm, for which only a first axial section of portions 30 is effectively moved back inside portions 23).

[0025] In any case, it will be possible to approximate the effective response curve with a straight line approximation:

$$Y = P * X + Q.$$

where:

P = mean increase in longitudinal compression resistance per unit length during plastic deformation,
Q = longitudinal compression resistance at the start of plastic deformation.

[0026] By taking the values P and Q and the final crushing of the plastically deformable portions at the end of the test, it is possible to obtain the resistance values B and E, and check if they correspond to those set by design.

[0027] For correct distribution of energy absorption, the fluctuations in the effective response curve must have a maximum variance of 7.5% with respect to the straight line approximation; in other words, the effective response curve is included in an interval defined by an upper ideal straight line:

$$Y = P * X + (Q + 7.5\%)$$

and a lower ideal straight line:

$$Y = P * X + (Q - 7.5\%).$$

[0028] By way of example, Figure 5 shows a lower ideal straight line (e) and an upper ideal straight line (f) calculated with reference to curve (d) for a semi-structure 9.

[0029] The progressive increase in compression resistance as the longitudinal crushing grows allows the energy discharged onto the interfaces between the first carriages to be reduced and consequently avoids the collapse of the body 7 of these carriages. In fact, by keeping resistance B at a relatively low value, the impact energy is transmitted to the following carriages along the entire train 1, while the linear increase in compression resistance during plastic deformation still allows a sufficient quantity of energy to be absorbed as a whole during the collision. In other words, the energy that must be absorbed is also distributed on the interfaces following the first ones. Thanks to this distribution, the bodies 7 remain intact, while only the semi-structures 9 that control absorption are deformed.

[0030] Furthermore, to repair the train 1 after an accident, the semi-structures 9 are easy to substitute and hence repair costs are significantly lower with respect to known solutions, with regard to both the components and working times.

[0031] It is possible to mount the same interface 8 between each pair of adjacent carriages 2, without having to calibrate or design each interface in a dedicated manner with respect to the others.

[0032] Furthermore, the structural characteristics and the position of the semi-structures 9 allow the effects of a collision to be reduced with respect to known solutions and are effective in a wide range of situations (for example, both in cases of accidents on straight runs and on curves). In particular, the mounting of the seats 24 and the coupling to the plates 27 and 28 resist extremely well to torsion during accidents. Therefore, the semi-structures 9 could theoretically also be used in solutions where energy absorption does not increase with crushing, but where the compression resistance of the plastically deformable portions is substantially constant during plastic deformation, as in known solutions.

[0033] Finally, from the foregoing, it is clear that modifications and variants can be made to the described and illustrated interfaces 8 of the train 1 without leaving the scope of protection of the present invention.

[0034] In particular, the plastically deformable portions with progressive energy absorption could be placed in different positions from those indicated by way of example, and/or be associated with the bar 10 or a different connection system between the bodies 7, instead of constituting part of separate structures.

Claims

1. A train (1) comprising:

- a plurality of carriages (2), in line and coupled together in a longitudinal direction (3), and
- an associated interface (8), between each pair of adjacent carriages, comprising plastically deformable portions (23,30) that plastically deform when a longitudinal compression load exceeds a preset threshold (B),

characterized in that, in each interface (8), during plastic deformation said plastically deformable portions (23,30) provide resistance to longitudinal compression, the mean progression of which has at least an initial stage where it grows as the longitudinal crushing of said plastically deformable portions

(23,30) increases.

2. The train according to claim 1, **characterized in that**, in each interface (8), during plastic deformation said plastically deformable portions (23,30) provide resistance to longitudinal compression, the mean progression of which grows in a monotonic manner up to a maximum longitudinal crushing (D) of said plastically deformable portions (23,30).

3. The train according to claim 1 or 2, **characterized in that** said mean progression grows linearly.

4. The train according to claim 3, **characterized in that**, in each interface (8), during plastic deformation said plastically deformable portions (23,30) provide resistance to longitudinal compression that can be represented by a curve as a function of longitudinal crushing, it being possible to approximate said curve with a straight line:

$$Y = P * X + Q;$$

and delimit it between an upper theoretical straight line: $Y = P * X + (Q + 7.5\%)$
and a lower theoretical straight line:

$$Y = P * X + (Q - 7.5\%);$$

where
Y = longitudinal compression resistance,
X = longitudinal crushing during plastic deformation,
Q = compression resistance at the start of plastic deformation,
P = mean increase in compression resistance per unit length during plastic deformation, and
7.5% = maximum permitted variance with respect to a mean linear progression.

5. The train according to any of the previous claims, **characterized in that** each interface (8) comprises two semi-structures (9) respectively carried by two adjacent carriages, arranged above a connection bar (10) between the two adjacent carriages, longitudinally spaced apart from each other during normal running conditions, substantially equal to each other and substantially symmetrical to each other with respect to an ideal plane orthogonal to said longitudinal direction (3).

6. The train according to claim 5, **characterized in that** the two semi-structures (9) of each interface (8) comprise:

- respective anti-climber members (12) that face each other and are substantially rigid, and
- respective energy absorption devices (18), which comprise said plastically deformable portions (23,30), and are fixed at one end to the bodies (7) of said carriages and carry said anti-climber members (12) at the opposite end.

7. The train according to claim 6, **characterized in that** the energy absorption device (18) of each semi-structure (9) comprises two buffer members (18) parallel to said longitudinal direction (3), both the same and mutually symmetrical with respect to an ideal longitudinal-vertical plane and coupled to each other at one end via said anti-climber member (12).

8. The train according to claim 7, **characterized in that** the two buffer members (18) comprise respective end portions (23) housed in fixed positions, in respective seats (24) defined by a body (7) of the relevant carriage (2), each said seat (24) being defined by two plates (27 and 28) longitudinally spaced apart from each other.

9. The train according to any of the previous claims, **characterized in that** it is defined as a high-speed train and that, in each said interface (8), said plastically deformable portions (23,30) provide resistance to longitudinal compression between $1.48 * 10^6$ and $1.72 * 10^6$ [N] at the start of plastic deformation, and resistance to longitudinal compression between $2.4975 * 10^6$ and $2.9025 * 10^6$ [N] when a crushing value (C) equal to approximately 610 [mm] is reached.

FIG. 1

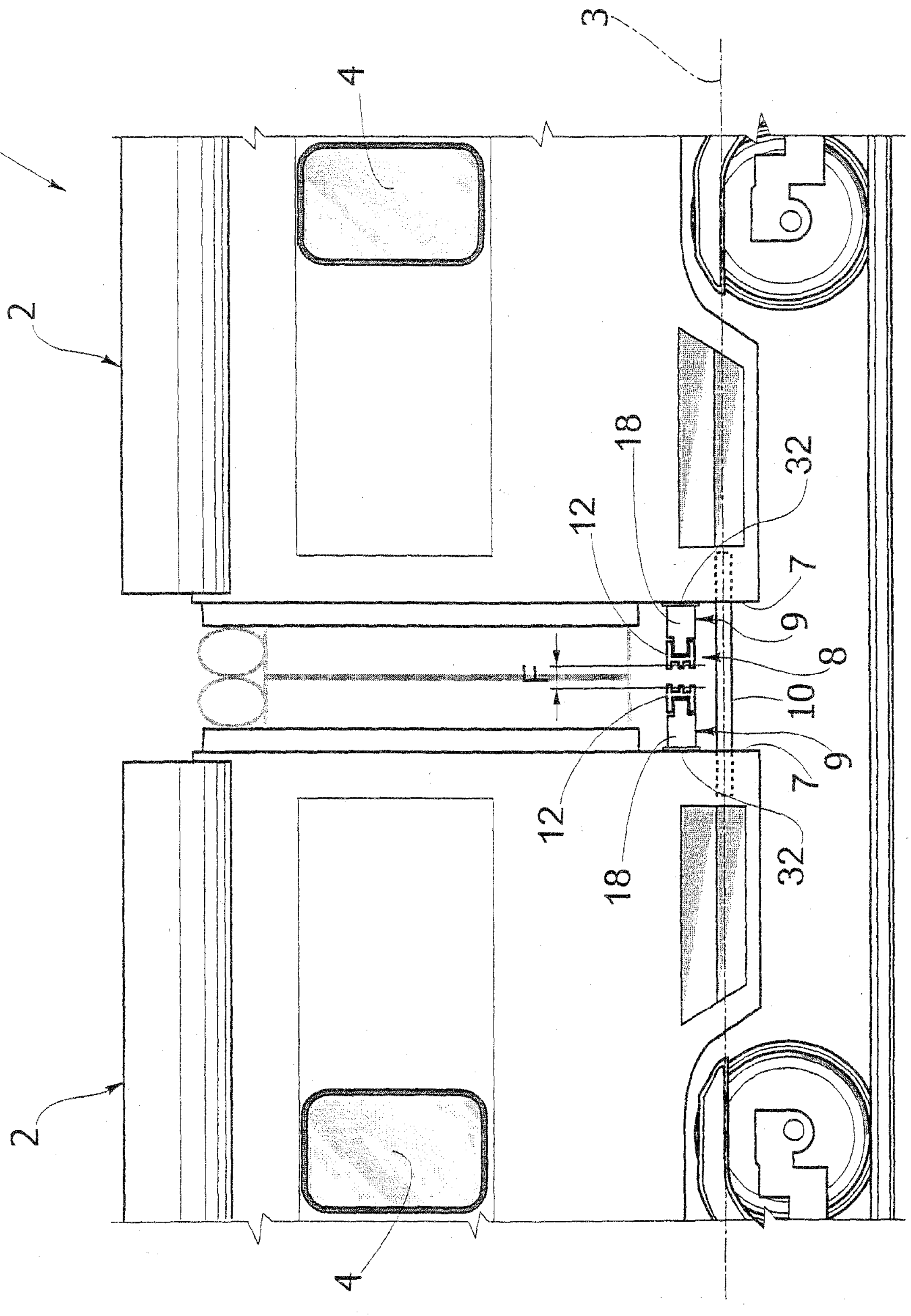


FIG. 2

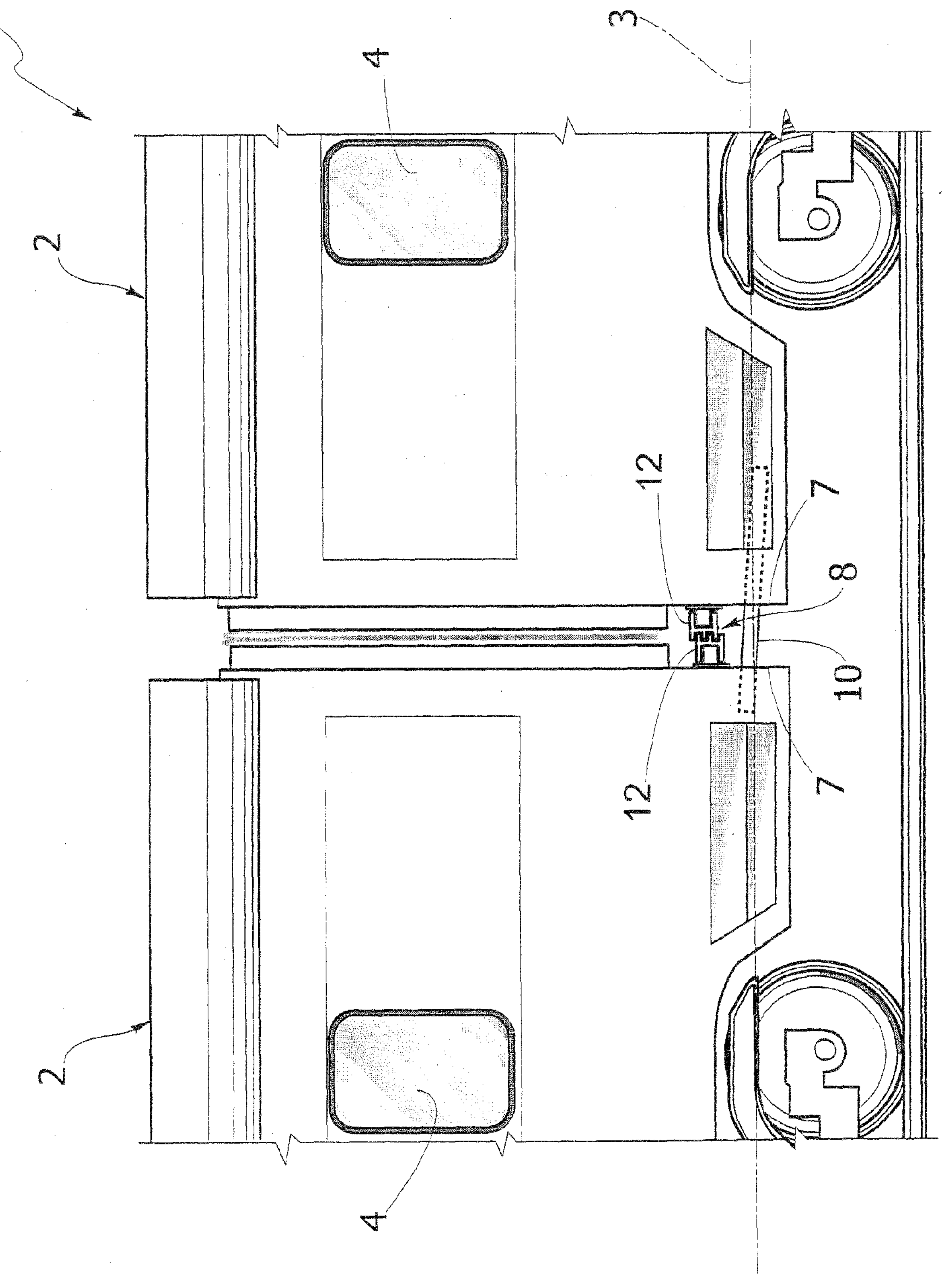


FIG. 3

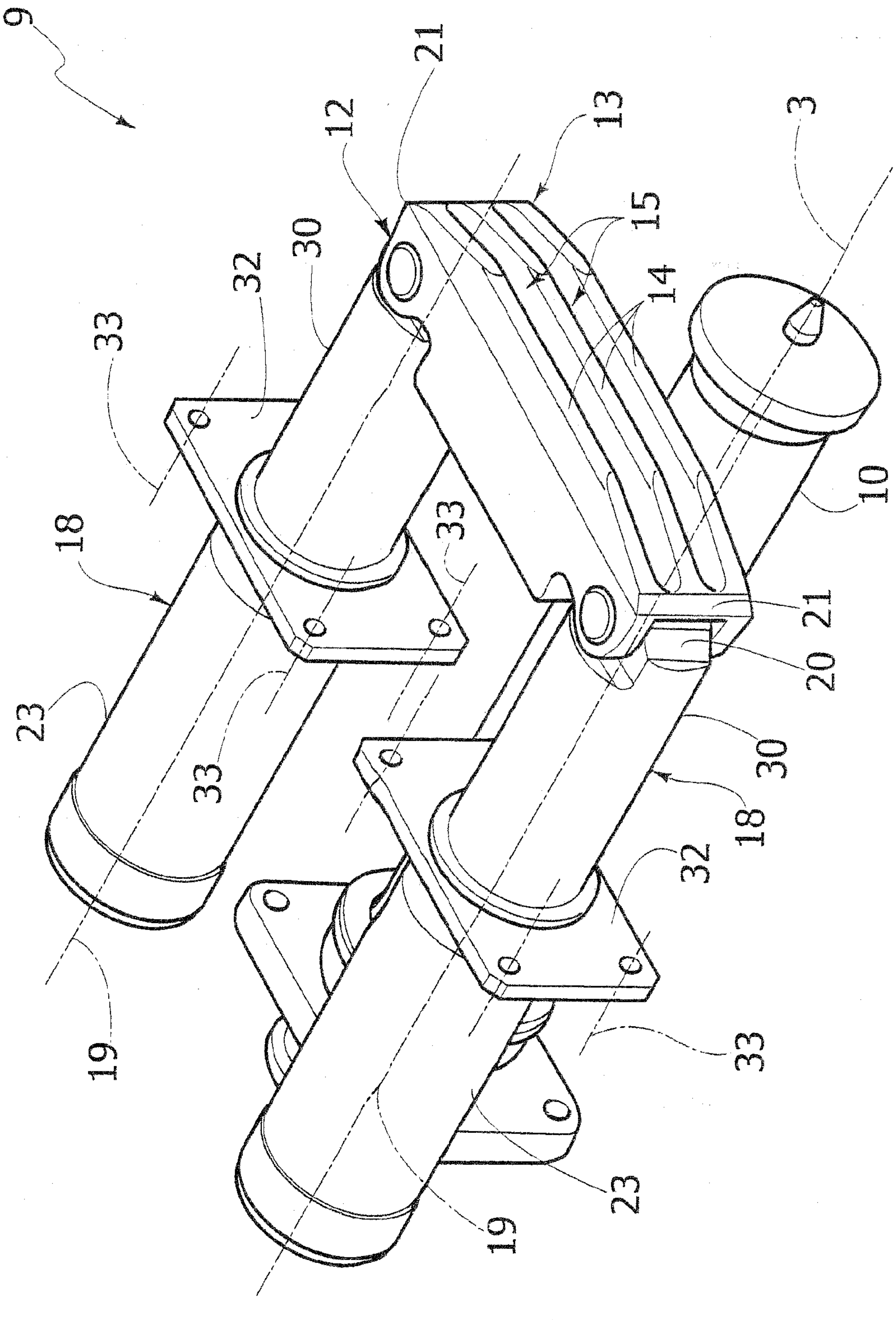


FIG. 4

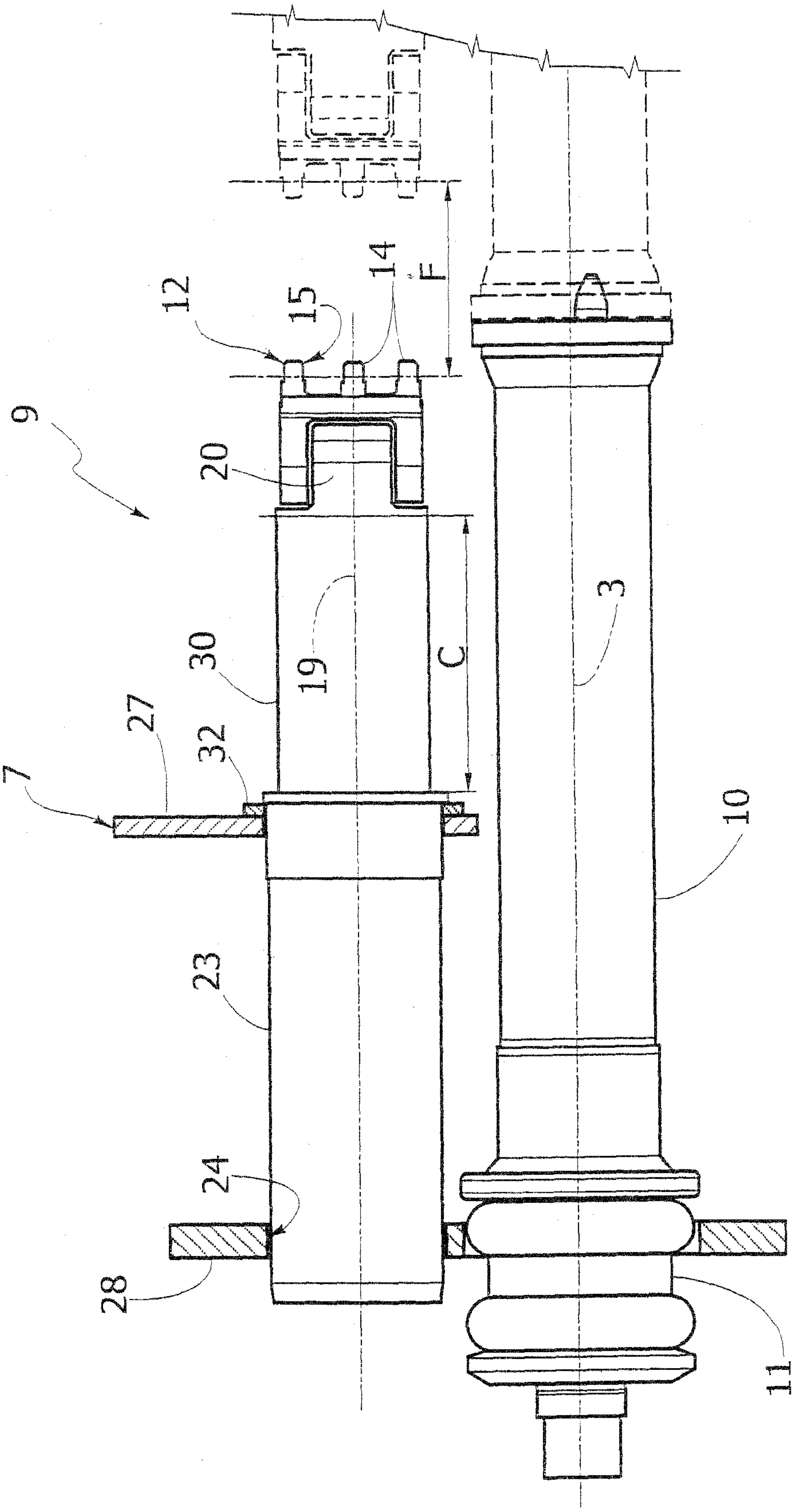
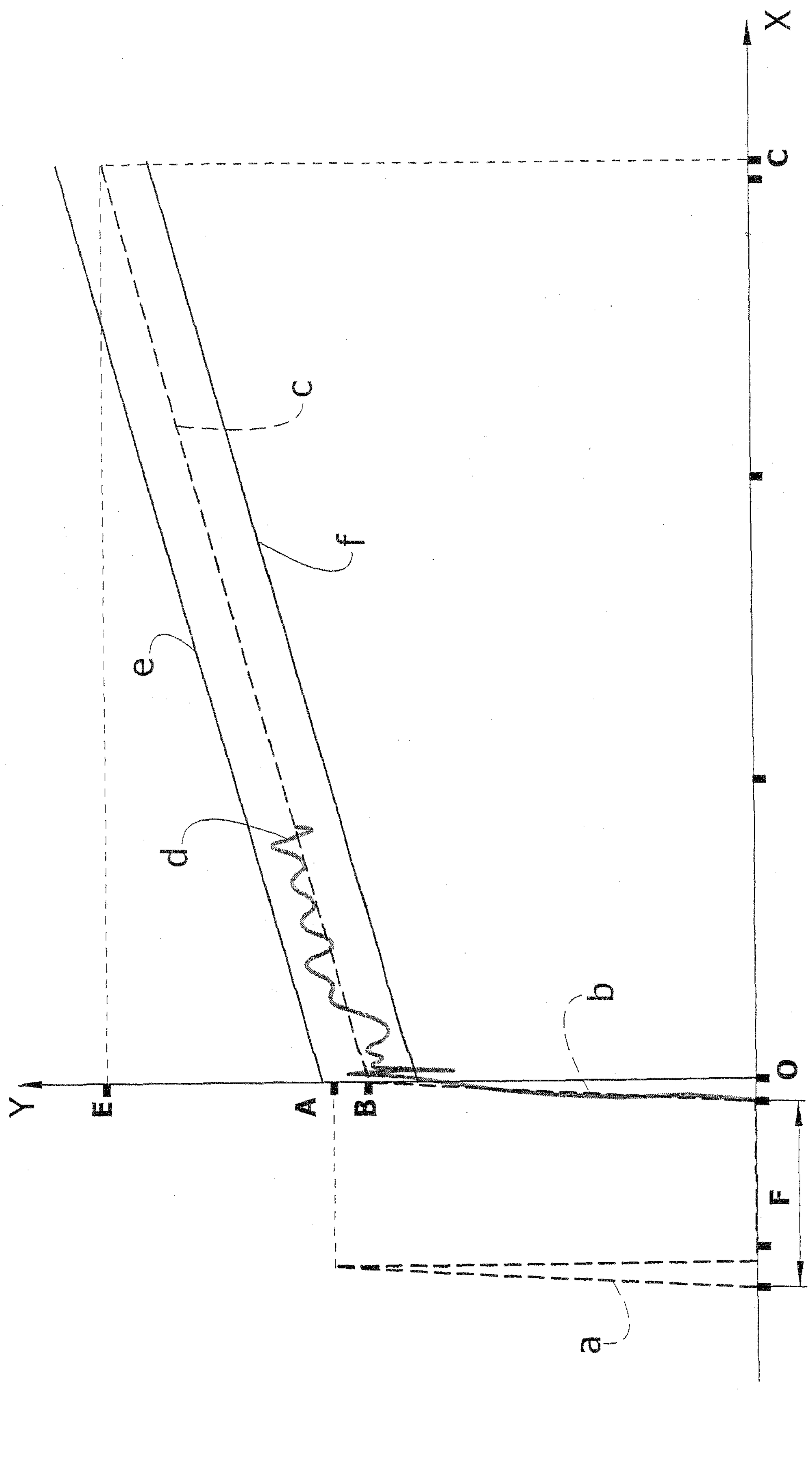


FIG. 5



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4

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	11 March 2008	Wojski, Guadalupe

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