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(54) Support for explosion-resistant panels

(57) A support (1) for an explosion-resistant panel (2) comprises at least one dissipating member (4) and members (1a, 1b 1c, 1d, 1e; 5a, 7a) suitable for contacting and/or connecting the support (1) to the panel (2) and the main frame (3) of a building respectively, the support (1) being suitable to transmit a blast force generated by an explosion along a stress axis (A) passing through the contacting and/or connecting members (1a, 1b; 1c, ld, 1e; 5a, 7a), the sections of the dissipating member (4) transversally arranged with respect to said stress axis (A) having a variable surface area along the stress axis (A). The function mathematically representing the profile of the dissipating member (4) along the stress axis (A) comprises one or more discontinuity points and the portions of the dissipating member (4) resulting from such discontinuous profile are made of the same or different materials.

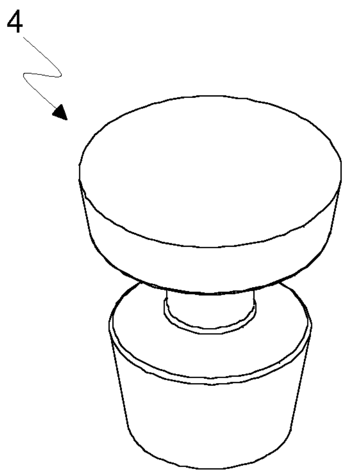

Fig.3

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Description

[0001] The present invention relates to a support for explosion-resistant panels that can be used in the field of constructions or in particular manufacturing activities as modular elements for the manufacturing of building walls or of equipment intended to contain explosive materials or mixtures.

[0002] In the past, explosion-proof constructions were mainly used in the field of defense e.g. for the manufacturing of weapons and ammunitions depots or of installations subject to the risk of bombardment. Nowadays these constructions are more and more diffused and employed not only in the field of defense but also in civil and industrial constructions comprising environments subject to the risk of explosion.

[0003] An explosion in a closed environment in fact generates a shock wave, i.e. compressed air that is directly moved by the blast force generated by the explosion, and projectiles that are detached in the form of fragments from the walls and/or ceilings of the construction. Secondary explosions are also possible that can even exceed the destructive ability of the shock wave initially generated by the explosion in the closed environment and therefore greatly increase the extent of the damages.

[0004] Explosion-proof constructions comprise walls formed of a plurality of panels suitable to withstand the high blast forces caused by an explosion by being deformed without being fragmented thus generating secondary projectiles. Thanks to the possibility of being deformed, these walls also allow to minimize the stresses transmitted to the bearing structure of a building.

[0005] Patent US 7406806 describes, for example, explosion-resistant panels comprising layers of masonry or plaster between which a layer of thermoplastic resin reinforced with glass fiber is arranged. Each panel is mounted on the bearing structure of a building by means of suitable supports fixed e.g. by welding or bolting. Upon an explosion, the supports transmit the blast forces along a stress axis passing through the points in which they are in contact with or connected to the panel and the bearing structure. The supports comprise one or more dissipating members suitable to be deformed by partially or completely absorbing the blast forces. The dissipating members may have various shapes, e.g. undulated or zigzag, that, depending on the intensity of the blast force, may undergo an elastic or plastic deformation. The supports may also comprise damping members combined with the dissipating members, thus varying the characteristics of absorption of the blast energy and therefore the stresses transmitted to the bearing structure.

[0006] The dissipating members of known supports for explosion-resistant panels are designed to have a compression behaviour that is substantially linear when varying the force applied thereto. Therefore, once the yield stress threshold of the material is exceeded, the function of absorbing the blast forces is completely assigned to the panels. Since in most cases the yield stress threshold is exceeded very rapidly, there is observed a substantially step-like trend of the stresses transmitted to bearing structure, which may cause even great damages to the structure.

[0007] German utility model DE 20307778 describes a blast protection for a door and/or window opening in a building having a panel fixed over the opening and mounted on impact absorbing supports which hold the panel at a spacing from the opening. The supports are energy-absorbing and can include deformable supports having a variable surface area along the stress axis. Energy-absorbing supports include hydraulic and pneumatic dampers.

[0008] German utility model DE 8703099 discloses a support for explosion-resistant door panels comprising one or more cylindrical-shaped dissipating tubes and connection means for connecting the panel to a frame. The dissipating tubes are so arranged as to transmit blast forces along a stress axis perpendicular to the longitudinal axis of the dissipating tube, whereby the sections of the dissipating tube transversally arranged with respect to the stress axis have a variable surface area along the stress axis.

[0009] As taught in FR 2410119, which discloses an explosion-resistant door for closing and protecting the opening of a building with a large bay, the shape, e.g. triangular, of the dissipating members and their arrangement with respect to the stress axis has the effect of allowing a progressive dissipation of the blast forces urging the bearing structure, so that a much effective dissipating action is achieved.

[0010] Nevertheless, there is still the need for improving the structure and the operation mode of the supports for explosion-resistant panels.

[0011] It is therefore an object of the present invention to provide a support for explosion-resistant panels having an improved structure and allowing to improve the modulation characteristics of the stresses transmitted to the bearing structure of a building upon an explosion, thus accomplishing together with the explosion-resistant panels a much effective dissipating action. Said object is achieved with a support whose main features are disclosed in the first claim, while other features are disclosed in the remaining claims.

[0012] The sections of the dissipating member of the support according to the invention that are arranged transversally to the stress axis passing through the contacting points and/or connecting members of the support to the panel and to the bearing structure have discontinuity of surface area or materials along the axis. In particular, the profile of the dissipating member along the stress axis is characterized by one or more discontinuity points. Moreover, the portions of the dissipating member resulting from such discontinuous profile may be made of the same or different materials. Hence, the designer can freely set the behaviour and particularly the mechanical impedance of the dissipating member upon the application of a blast force. The dissipating member can thus be easily designed to so that the stress waves transmitted to the bearing structure are partially or completely blocked/reflected by simply choosing a suitable ratio of the surface areas at the discontinuity point or points and/or a particular combination of materials, or in order to concentrate the largest part of the blast energy in specific points of the dissipating member.

[0013] In this way the support is no longer just a connecting member between a panel and the bearing structure of a building or an equipment that may be subject to an explosion, but does become a member suitable to filter the stresses caused by an explosion, that determines the deformation mode of the panel and the stresses transimitted to the bearing structure.

[0014] An advantage of the support according to the present invention is that the dissipating member can be arranged in a container closed at one end and comprising a pressure member arranged in contact with the dissipating member at its free end. Thanks to the use of a container it is possible to accomplish both a containing and a guiding function of the dissipating member, so that any lateral displacement of the dissipating member and the panel under the blast force can be prevented, thus further improving the structural characteristics and the operation mode of the support.

[0015] The pressure member can be advantageously provided with an enlarged head portion that defines a shoulder suitable to limit its movement along the axial direction.

[0016] Another advantage of the invention is that, depending on the design needs, the support may be designed with one or more pre-set breaking points.

[0017] Still another advantage offered by the invention is that the dissipating member of the support may be combined in series or in parallel with dampers of a hydraulic, pneumatic or similar type, thus allowing to vary and optimize the transmission mode of the blast force generated by an explosion.

[0018] Further advantages and features of the support according to the present invention will become clear to those skilled in the art from the following detailed and non-limiting description of some embodiments thereof with reference to the attached drawings, wherein:

- figure 1 shows a schematic perspective view of a first embodiment of the dissipating member of the support according to the invention;
- figure 2 shows a schematic perspective view of a second embodiment of the dissipating member of the support according to the invention;
- figures 3 to 5 show further embodiments of the dissipating member of the support according to the invention;
- figure 6 shows a schematic perspective view of the support of the invention;
- figure 7 shows an exploded view of the support of figure 6; and
- figure 8 shows a longitudinal cross-section taken along line VIII-VIII of figure 6.

[0019] Figures 1 and 2 schematically show two embodiments of a support 1 wherein only the dissipating member is shown in order to better explain its characteristics and operation mode.

[0020] Figure 1 schematically shows a support 1 arranged between an explosion-resistant panel 2 and the bearing structure 3 of a building or an equipment. The support 1 comprises contact members, e.g. a pair of flanged surfaces 1a, 1b, suitable to allow the contact between support 1, panel 2 and the bearing structure 3, respectively. Therefore, in the case of an explosion the support 1 transmits the blast force generated by the explosion along a stress axis A passing through the contact members 1a, 1b. The contact members 1a, 1b might also be used to connect the support to panel 2 and structure 3, e.g. by welding or bolting.

[0021] The support 1 further comprises in a known way at least one dissipating member 4 arranged between the contact members 1a, 1b and suitable to be deformed while partially or completely absorbing the impact energy generated by the explosion.

[0022] The sections of the dissipating member 4 transversally arranged to the stress axis A have a variable surface area along the stress axis A. Therefore, a blast force caused by an explosion generates in the support according to the invention stresses having a variable intensity along the stress axis A, thus allowing the support to carry out a dissipating action that may be graduated on the basis of the design needs.

[0023] In the embodiment shown in figure 1, the stress axis A coincides with the longitudinal axis of the dissipating member 4 that has, in particular, a frustoconical shape. A blast force resulting from an explosion will cause variable stresses along the axial direction starting from the section having the smallest surface area to the section having the largest one, decreasing stresses in particular, whereby, depending on the intensity of the force applied to the dissipating member 4 and on the material of which this is made, it will be possible that the yield stress threshold is exceeded at the sections having a smaller surface area and that an elastic behaviour is maintained at the sections having a larger surface area.

[0024] Alternatively, the dissipating member 4 might have a pyramid, hourglass, or similar shape.

[0025] In the embodiment shown in figure 2, the stress axis A is instead perpendicular to the longitudinal axis B of the dissipating member 4. The dissipating member 4 has in this case a cylindrical shape with a circular cross-section and the stress axis A passes through a diameter of a circular cross-section thereof. The contact members are in this case formed by two diametrically opposed cylinder generatrices 1c, 1d, while the connection may be carried out e.g. by means of a through-hole 1e whose axis passes through the diameter of a circular cross-section of the dissipating member 4.

[0026] Alternatively, the dissipating member 4 might also have a cylindrical shape with a non-circular cross-section, e.g. elliptical or polygonal.

[0027] Depending on the design needs, the support may comprise more dissipating members 4 arranged in series or in parallel.

[0028] The dissipating members 4 may have different shapes with respect to one another and/or be made of materials having a different elastic modulus, density and generally other physical characteristics that be useful to change impedance, such as the Poisson coefficient, thus allowing to achieve a large number of embodiments of the support and to achieve a different mechanical impedance along the stress axis.

[0029] Moreover, the inventor has found that the design of the dissipating member 4 can be significantly improved by introducing one or more discontinuities along the stress axis A, i.e. one or more discontinuity points in the function mathematically representing the profile of the dissipating member 4 along the stress axis A. Moreover, the portions of the dissipating member 4 resulting from such discontinuous profile may be made of the same or different materials. This has the effect of allowing the designer to freely set the behaviour of the dissipating member 4 upon the application of a blast force. The dissipating member 4 can thus be designed e.g. to partially or completely block or reflect the stress waves transmitted to the bearing structure 3, or to let them completely pass, by simply choosing a suitable ratio of the surface areas at the discontinuity point or points or different materials. Moreover, pre-set breaking points can be introduced, thus further improving the design configurations of the dissipating member 4.

[0030] The different portions of the dissipating member 4 so designed can be integral with each other or individual bodies arranged adjacent to each other and possibly made of different materials.

[0031] Figures 3, 4 and 5 show three different embodiments of the dissipating member 4 in which the profile is characterized by discontinuity points. In particular, figure 3 shows a dissipating member 4 having a substantially frustoconical shape with a deep circumferential groove at a mid-portion thereof. Conversely, figure 4 shows a dissipating member 4 having a substantially frustoconical shape having an enlarged mid-portion. Figure 5 shows a dissipating member 4 having two discontinuity points so configured that a stepped profile is formed at a mid portion thereof. In particular, the portion having the largest diameter can be e.g. designed so as to be elastically deformed by the blast force, whereas the portion having the smallest diameter and the intermediate portion can be designed so as to progressively yield at predefined stress thresholds.

[0032] According to the invention, the dissipating member 4 may be free from the bearing structure 3 and the panel 2 and inserted in a suitable container that accomplishes both a containing and a guiding function of the dissipating member 4.

[0033] As shown in figures 6 to 8, the container comprises a tubular member 5 closed at one end and a pressure member 6 having a substantially cylindrical shape and suitable to transmit a blast force to the dissipating member 4. The dissipating member 4 shown in figures 6 to 8 has a frustoconical shape, but it is clear that any shape of the dissipating member 4 may be used in combination with the container.

[0034] The dissipating member 4 is inserted at least partially and e.g. coaxially in the tubular member 5, and the pressure member 6 is arranged in contact with the dissipating member 4, e.g. at its free end when the dissipating member is coaxially arranged in the tubular member 5. Therefore, the tubular member 5 of the support according to the invention accomplishes a guiding and containing function of the dissipating member 4 during the application of the blast force along the axial direction.

[0035] Preferably, as shown in the figures, the dissipating member 4 is completely inserted in the tubular member 5 and the pressure member 6 is sized so as to be partially inserted in the tubular member 5 thus closing its open end. The pressure member 6 is further provided with an enlarged head portion 7 that defines a shoulder 8 suitable to limit its movement along the axial direction.

[0036] In another embodiment (not shown), the dissipating member 4 is inserted in the tubular member 5 transversally to its longitudinal axis, so that a more compact configuration of the support may be obtained.

[0037] The tubular member 5 and the pressure member 6 are respectively provided with contact members, e.g. flanged surfaces 5a, 7a, which allow to simply contact or to contact and connect support 1 with panel 2 and structure 3.

[0038] It is clear that the embodiments of the support herein described and illustrated are only examples susceptible of numerous variants. For example, the support according to the invention may comprise one or more damping members, e.g. of a hydraulic or pneumatic type, associated with the dissipating member. The damping members may be arranged in series or in parallel with respect to the dissipating member and allow to make systems for absorbing blast forces in which the transmission of the stresses depends on both the shape of the dissipating member and the velocity with which the blast forces are applied.

Claims

1. A support (1) for an explosion-resistant panel (2), which comprises at least one dissipating member (4) and members (1a, 1b; 1c, 1d, 1e; 5a, 7a) suitable for contacting and/or connecting the support (1) to the panel (2) and the main frame (3) of a building respectively, the support (1) being suitable to transmit a blast force generated by an explosion along a stress axis (A) passing through the contacting and/or connecting members (1a, 1b; 1c, 1d, 1e; 5a, 7a), the

sections of the dissipating member (4) transversally arranged with respect to said stress axis (A) having a variable surface area along the stress axis (A), **characterized in that** the function mathematically representing the profile of the dissipating member (4) along the stress axis (A) comprises one or more geometrical discontinuity points and **in that** the portions of the dissipating member (4) resulting from such discontinuous profile are made of the same or different materials.

2. A support according to the previous claim, **characterized in that** the dissipating member (4) is integrally formed with the contacting and/or connecting members (1a, 1b; 1c, 1d, 1e; 5a, 7a).

3. A support according to any of the previous claims, **characterized in that** the stress axis (A) coincides with the longitudinal axis of the dissipating member (4).

4. A support according to claims 1 or 2, **characterized in that** the stress axis (A) is perpendicular to the longitudinal axis (B) of the dissipating member (4).

5. A support according to any of the previous claims, **characterized by** comprising a plurality of dissipating members (4) arranged in series or in parallel.

6. A support according to the previous claim, **characterized in that** the dissipating members (4) are made of materials having different elastic modulus and/or density and/or Poisson coefficient.

7. A support according to any of the previous claims, **characterized by** further comprising at least one damping member associated with the dissipating member (4).

8. A support according to the previous claim, **characterized in that** the damping member (4) is arranged in series or in parallel with respect to the dissipating member (4).

9. A support according to any of the previous claims, **characterized in that** the dissipating member (4) is arranged in a container (5, 6).

10. A support according to the previous claim, **characterized in that** the container (5, 6) comprises a tubular member (5) closed at one end and a pressure member (6) suitable for transmitting a blast force to the dissipating member (4), the dissipating member (4) being at least partially inserted in the tubular member (5) and the pressure member (6) being arranged in contact with the dissipating member (4) at its free end.

11. A support according to the previous claim, **characterized in that** the dissipating member (4) is completely inserted in the tubular member (5), the pressure member (6) being so sized as to fit the tubular member (5) closing its open end.

12. A support according to the previous claim, **characterized in that** the pressure member (6) is provided with an enlarged head portion (7) defining a shoulder (8) suitable to restrict its movement in the axial direction.

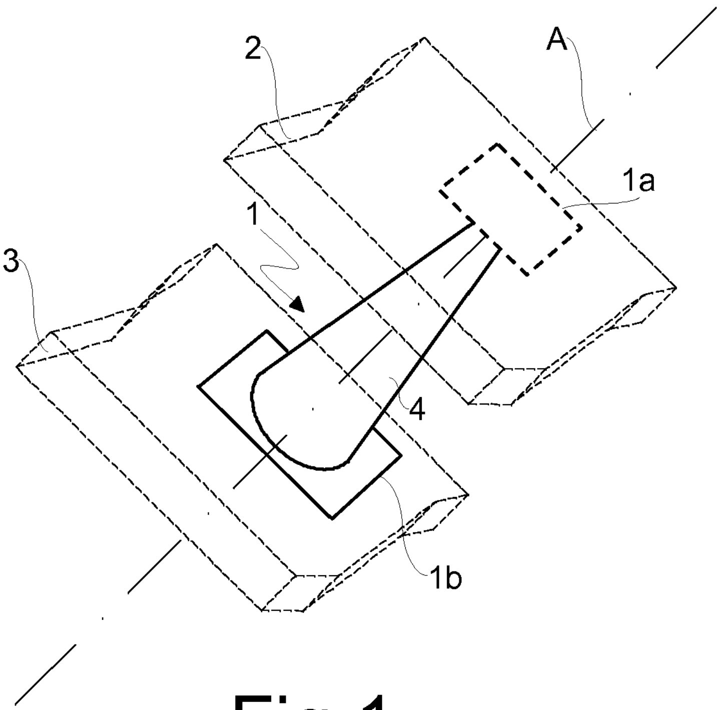

Fig.1

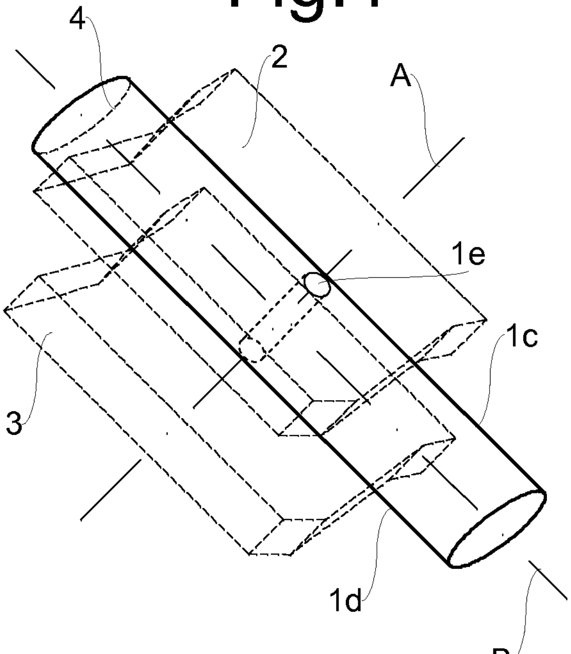

Fig.2

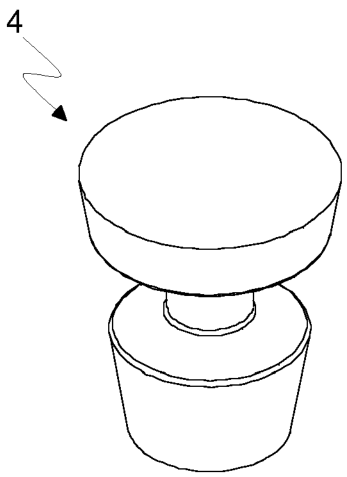

Fig.3

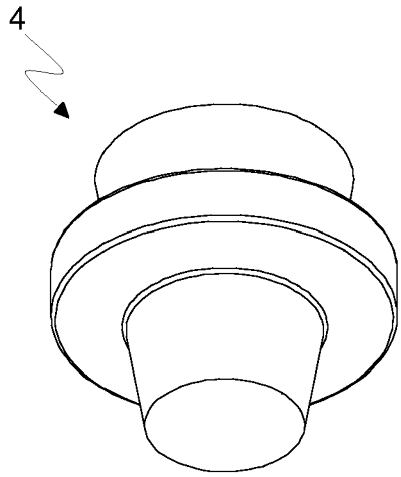

Fig.4

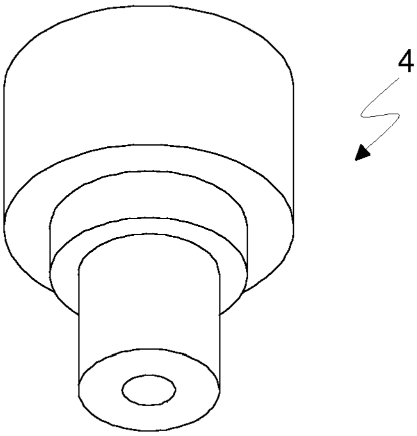

Fig.5

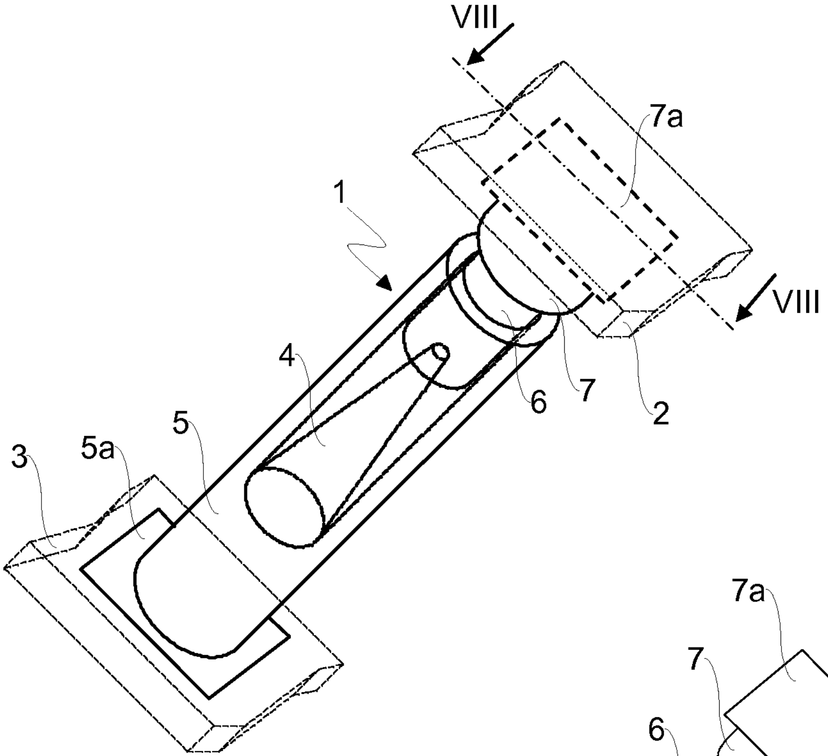

Fig.6

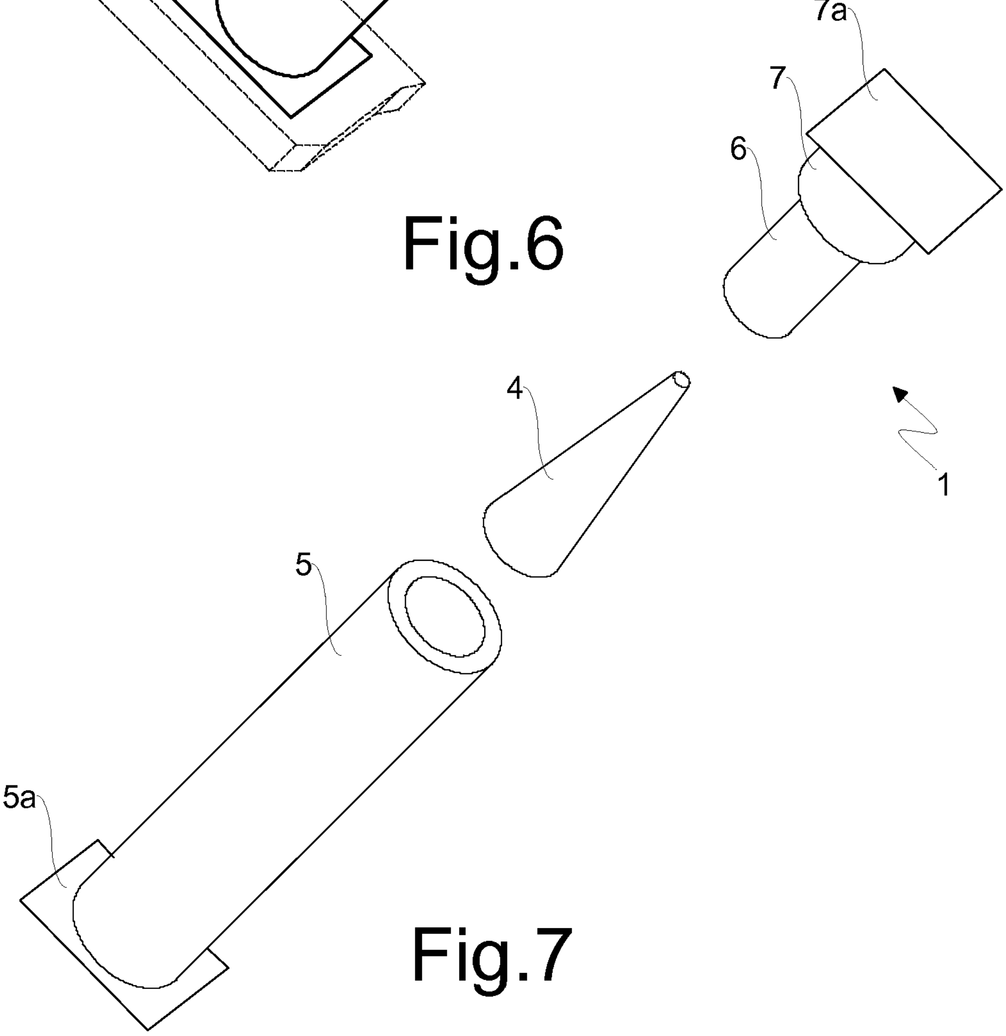

Fig.7

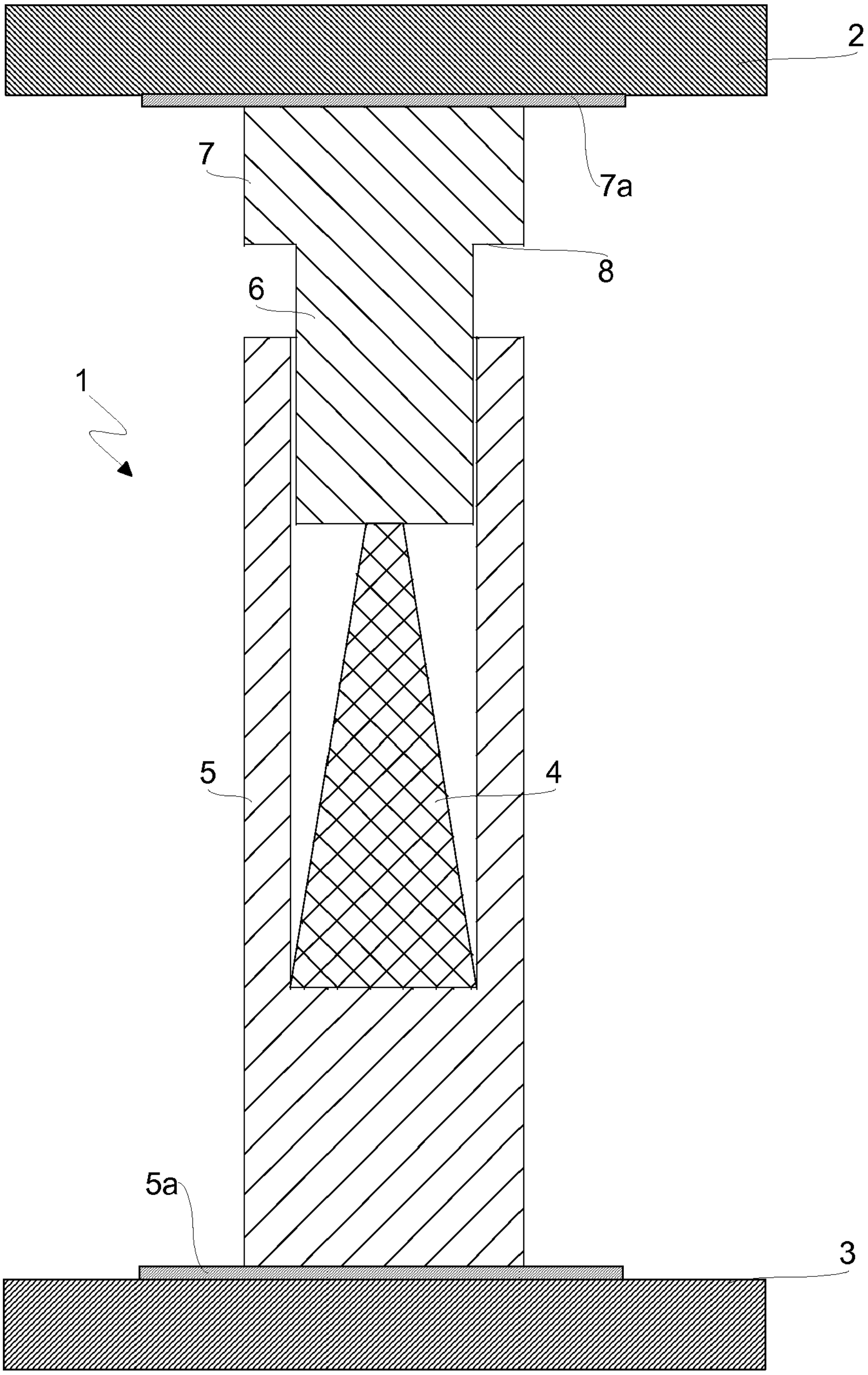

Fig.8

REFERENCES CITED IN THE DESCRIPTION

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