

BALLISTIC LAYER AND BALLISTIC MULTILAYER ARRANGEMENT

The invention relates to a ballistic multilayer
5 arrangement to defend against projectiles or other highly-accelerated components.

Ballistic plates are used in all kinds of armour, be it on
vehicles, aircraft, buildings or directly portable on
10 persons. In most instances the very heavy weight of the plates is disadvantageous, which plates necessarily have to be of sufficient thickness to satisfy the requirements of a particular ballistic level.

15 The above is disadvantageous, for example in passenger transport vehicles that by means of armour comprising thick steel plates have to provide protection against ballistic threats, which plates as a result of the heavy weight also render the vehicles slow and cumbersome.

20 For this reason in the further state of the art multilayer plates are used, which are, however, expensive to manufacture or do not meet the high but required ballistic levels. Fig. 5 shows a known ballistic plate 9 which on
25 the impact side comprises a ceramic plate 91 by means of which a projectile is to be decelerated, and at best partially disaggregated, followed by one or several layers of aramid fibres 92, and finally a steel plate 93.

30 In particular in the case of modern projectiles with ceramic material cores (for example tungsten carbide) or high-energy projectiles, as a result of the layer

thicknesses necessary for defence these plates become too heavy or very expensive to manufacture.

It is the object of the invention to provide a ballistic
5 multilayer arrangement that is both reliable and saves material during manufacture.

This object is met by a ballistic layer for a ballistic multilayer arrangement according to the characteristics of
10 claim 1 and a ballistic multilayer arrangement according to the characteristics of claim 10.

According to the invention according to a first aspect of the invention it is proposed to design a ballistic layer
15 for a ballistic multilayer arrangement in such a manner that it is formed by an absorption layer that entirely or largely comprises expanded glass. Suitable foam glass that has the same characteristics is included in the sense of the invention.

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In this manner stopping the incoming projectile or fragment becomes possible in a particularly effective manner. The energy is absorbed to a high degree by the absorption layer.

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The term "expanded glass" refers to foamed glass with small gas-filled or air-filled pores. Expanded glass can be produced in various grain sizes.

30 A very economical and thus advantageous variant of the invention provides for the expanded glass to be present in the form of sintered expanded-glass granulate.

In the sense of the invention the layer can be provided so as to be flexible as a mat or a blanket, or in particular with the further embodiments as a rigid plate.

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As a rigid composite structure the ballistic layer can be present as expanded glass, and according to a further advantageous embodiment of the invention in the form of sintered expanded-glass granulate.

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A particularly advantageous and thus preferred embodiment of the invention provides for the expanded glass to be present in the form of expanded-glass granulate held in a dense packing or fill by means of a matrix that encloses the expanded-glass granulate. In this arrangement the granulate beads tightly adjoin each other and are at least partly enclosed by the matrix.

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Preferably, the expanded-glass granulate comprises a granulate size of 0.01 mm to 5 mm.

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Furthermore, it is preferred if the expanded glass or expanded-glass granulate predominantly comprises SiO_2 . Further preferably as further ingredients the expanded glass or expanded-glass granulate comprises Na_2O and CaO , and equally preferably as further ingredients comprises a small amount, in each case below 10 percent weight by weight, of Al_2O_3 and/or MgO and/or K_2O .

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According to a particularly advantageous embodiment of the invention the matrix of the expanded-glass granulate comprises a synthetic material or a synthetic resin or a

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mixture of synthetic material/synthetic resin, which mixture is, in particular, impact-resistant. This makes it possible to achieve particularly good absorption of the energy of the projectile.

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Consequently, it is advantageously provided that the synthetic material mixture comprises polyurethane and/or polyethylene and/or epoxy resin and/or silicon and/or an impact-proof synthetic material and/or an impact-resistant synthetic material.

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According to a further embodiment of the invention, a ballistic multilayer arrangement with an impact side and a back and a ballistic layer according to any one of claims 1 to 9 is proposed, wherein at least one of the layers of the ballistic multilayer arrangement is formed by a multilayer fibre layer comprising layers of aramid fibres or comparable fibres, wherein said multilayer fibre layer is, in particular, designed in the form of a woven material or a multilayer woven material.

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Advantageously it is provided for the at least one of the layers to be formed by a plate comprising fine stone or natural stone or ceramic or a ceramic mix, in particular comprising a composite-structure material. In this manner a projectile can be decelerated very effectively by means of the necessary destruction force of the plate, and can be partially disaggregated and moved from its trajectory, which in the following layers improves the effectiveness by a broadened contact surface.

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Lightweight projectiles or low-energy projectiles can be entirely kept off by such a layer.

When penetrating the layers a projectile can also very
5 effectively be deflected by a spall layer, preferably a
spall layer provided according to an improvement of the
invention. To this effect it is proposed that the spall
layer is formed by spalls comprising spalls of ceramic or
ceramic metal or fine stone or natural stone, which spalls
10 are bound in a matrix.

Preferably at least one layer of the ballistic multilayer
arrangement is formed by a metal plate.

15 Advantageously at least one layer can be formed by a
highly tenacious synthetic layer that in this arrangement
can preferably be formed by the highly tenacious synthetic
layer of the matrix of the absorption layer.

20 Advantageously the arrangement is surrounded by a
synthetic cover layer or a fibre-reinforced synthetic
braiding layer at least on one side of the impact side and
the back. Consequently the structure of regions beside an
impact are better preserved and, for example, a fractured
25 or broken ceramic plate retains its function in a region
beside a location of impact.

Preferably in the layer sequence the absorption layer is
followed at least on one of its sides by a fibre layer.

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In a plate-like design, apart from the absorption plate,
advantageously at least one fine stone layer, natural

stone layer or ceramic layer, a fibre layer and a metal layer are provided.

A particular embodiment provides for the layer sequence to be selected as follows:

- an enveloping layer,
- a ceramic/fine stone/natural stone layer, in particular followed by a metal layer,
- a fibre layer and an absorption layer sequence,
- a metal layer.

Further advantageous embodiments are stated in the further subordinate claims or their possible subordinate combinations.

Below, the invention is explained in more detail with reference to the drawings. The following are diagrammatically shown in:

- Fig. 1 a diagrammatic view of a ballistic multilayer arrangement with an absorption layer according to the invention and on the impact side an upstream fibre layer,
- Fig. 2 a diagrammatic view of a ballistic multilayer arrangement with an absorption layer according to the invention and on the impact side a downstream fibre layer,
- Fig. 3 a diagrammatic view of the absorption layer with expanded-glass granulate and the matrix enclosing the expanded-glass granulate,

- Fig. 4 a diagrammatic exemplary view of a cross-section
of an expanded-glass granulate,
- 5 Fig. 5 a diagrammatic view of a ballistic plate
according to the state of the art,
- Fig. 6 a diagrammatic view of an exemplary ballistic
multilayer arrangement with an absorption layer
10 according to the invention according to a first
variant,
- Fig. 7 a diagrammatic view of an exemplary ballistic
multilayer arrangement with an absorption layer
15 according to the invention according to a second
variant,
- Fig. 8 a diagrammatic view of an exemplary ballistic
multilayer arrangement with an absorption layer
20 according to the invention according to a third
variant,
- Fig. 9 a diagrammatic view of an exemplary ballistic
multilayer arrangement with an absorption layer
25 according to the invention according to a fourth
variant with a spall layer, and
- Fig. 10 a diagrammatic view of an exemplary ballistic
multilayer arrangement according to a fifth
30 variant with a multiple absorption layer-sequence
according to the invention.

Identical reference characters in the figures designate identical elements or elements that have the same effect.

5 Fig. 1 shows a diagrammatic view of a ballistic multilayer arrangement 1 according to the invention. In this arrangement downstream of an aramid fibre layer 4, when viewed from the projectile impact side A, an absorption layer 2 in the form of a multilayer woven material is
10 arranged. Fig. 2 shows an alternative arrangement with the sequence of the absorption layer 2 and the fibre layer 4 being the other way round.

In all the exemplary embodiments the layers are
15 interconnected either mechanically or with the use of suitable adhesives.

The absorption layer 2 comprises expanded glass 21 in the form of expanded-glass granulate 22 held in a dense
20 *packing* by means of a matrix 24 enclosing the expanded-glass granulate, see Fig. 3. The matrix 24 is formed in an impact-resistant synthetic mixture. Good results have been achieved with impact-resistant polyurethane mixtures.

25 Expanded glass 21 is very light in weight and free of broken grains, highly thermally insulating, sound insulating, resistant to pressure, non-flammable, acid-proof and vermin-proof.

30 In the example the composition of the expanded-glass granulate 22 is as follows:

SiO_2 71 ± 2 % weight by weight

Na_2O 13 ± 1.5 % weight by weight

5 CaO 8 ± 2 % weight by weight

Al_2O_3 $2 \pm 1,3$ % weight by weight

MgO 2 ± 1 % weight by weight

K_2O 1 ± 0.2 % weight by weight

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and

Fe_2O_3 0.5 ± 0.2 % weight by weight
trace elements < 0.5 % weight by weight.

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The granulate 22 itself can be of a closed-pore or of an open-pore nature, with a granulate size of 0.01 mm to 5 mm. As is shown as an example in cross section in Fig. 4, the foamed expanded-glass granulate 22 has a bubble size
20 23 of 0.001 – 0.5 mm.

Depending on the configuration of the energy to be absorbed, the layer thickness of the absorption layer can be between 0.5 and 50 mm.

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In the examples the fibre layers 4 (41, 42, 43) are multilayer woven materials comprising aramid fibres. However, it is also possible to use comparable fibres.

30 It is imaginable to design the arrangement according to Fig. 1 or 2 so that it is elastic, and to select the matrix of the absorption layer correspondingly so that

manufacture of the ballistic multilayer arrangement as a mat or blanket is possible. Thus secure tents or curtains and the like are possible.

- 5 Fig. 6 shows an exemplary design of a ballistic multilayer arrangement 1 as a plate with an absorption layer 2.

The layer sequence viewed from the direction of the impact side A is as follows. On the outside first a synthetic
10 cover layer 8 is provided. This cover layer 8 is used as a finish towards the outside and ensures that any shattered components of the subsequent very hard first ceramic layer 5 do not fall out following a hit by a projectile, and that the structure is held together even in the case of
15 cracks in the ceramic layer 5 should a further hit in the surroundings of an impact occur.

In this arrangement in the sense of the invention the ceramic layer 5 can also comprise other materials such as
20 fine stone or natural stone or a ceramic mixture or a ceramic-metal mixture in plate-shape.

It is important that the "ceramic" layer 5 is hard. This can be provided either by classical ceramics or by
25 substitute materials such as very hard natural stone (granite etc.) or fine stone, which is very hard high-fired stoneware.

The ceramic layer 5 is followed by a fibre layer 4 of
30 woven aramide materials. This is followed by the absorption layer 2, which is able to absorb the energy of the projectile or fragment. In the absorption layer a

great deal of energy is absorbed by the projectile and in its further path is distributed to a much wider base so that after this a metal plate 7 is sufficient as a final layer.

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If even higher energies are input or if for reasons of weight reduction the layer thicknesses are selected so as to be thinner, according to Fig. 7 it is also possible to implement a variant in which in front of the steel plate 7
10 after a first fibre layer 41 immediately in front of the aforesaid a second fibre layer 42 is provided.

Fig. 8 shows a further modification, when compared to the embodiment of Fig. 7, in which after the ceramic layer 5 a
15 first steel plate 71 has been installed. This steel plate 71 additionally stabilises the ceramic layer in the immediate surroundings of an impact. This can be advantageous in the case of multiple projectile entry. In the example shown, too, a steel plate 72 is provided on
20 the back B. Said steel plate 72 can already be designed as a lightly armoured outer wall of a vehicle or as a normal outer wall.

Fig. 9 shows a further modification. In this case the
25 ceramic layer 5 is followed by a spall layer 6 that comprises ceramic spalls or ceramic-metal spalls or fine stone spalls or natural stone spalls 61 bound in a matrix 62. In this design it is not so much the layer sequence that is the essential characteristic, but rather the
30 presence of a spall layer bound in a matrix, which spall layer comprises a loose fill of very hard spalls that

deflect a projectile or a hard projectile core (for example tungsten carbide).

The example according to Fig. 10 shows an arrangement with
5 two successive absorption layers 2a and 2b, separated from
each other by a fibre layer 42. In the example shown both
absorption layers 2a and 2b are situated adjacent to a
further fibre layer 41 and 43 and following on from this
comprise a steel plate 71 and 72.

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The layers as shown in the above examples can also be
arranged in some other sequence, with some layers being
left out or arranged multiple times.

15 In the use of the absorption layers according to the
invention it is also very advantageous that said layers
provide outstanding thermal insulation characteristics.
Thus vehicles, structures or tents can be thermally
insulated from the outside world against heat or cold,
20 without this requiring a further layer or some other
measures.

Likewise the design of the absorption layer according to
the invention is sound insulating. This characteristic,
25 too, is advantageous in the proposed application.

List of reference characters

	1	Ballistic multilayer arrangement
5	A	Impact side
	B	Back
	2	Absorption layer
	2a, 2b	Absorption layer
	21	Expanded glass
10	22	Expanded-glass granulate
	23	Bubbles
	24	Matrix
	4	Fibre layer
	41	Fibre layer
15	42, 43	Fibre layer
	5	Ceramic plate
	6	Spall layer
	61	Spalls
	62	Matrix
20	7	Metal plate
	71, 72	Metal plate
	8	Synthetic cover layer
	9	Ballistic plate (state of the art)
	91	Ceramic plate
25	92	Fibre layer
	93	Steel plate

Claims

1. A ballistic layer for a ballistic multilayer
5 arrangement, wherein the ballistic layer is formed by an
absorption layer that entirely or largely comprises
expanded glass present in the form of sintered expanded
glass granulated held in dense packing of fill by means of
a matrix that encloses the expanded-glass granulate.
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2. The ballistic layer according to claim 1, wherein the
expanded-glass granulate comprises a granulate size of
0.01 mm to 5 mm.
- 15 3. The ballistic layer according to claim 1, wherein the
expanded glass or expanded-glass granulate predominantly
comprises SiO_2 .
4. The ballistic layer according to claim 1, wherein as
20 further ingredients the expanded glass or expanded-glass
granulate comprises Na_2O and CaO .
5. The ballistic layer according to claim 1, wherein as
further ingredients the expanded glass or expanded-glass
25 granulate comprises a small amount, in each case below 10
percent weight by weight, of Al_2O_3 and/or MgO and/or K_2O .
6. The ballistic layer according to claim 5, wherein the
matrix comprises a synthetic material or a synthetic resin
30 or a mixture of synthetic material/synthetic resin, which
mixture is, in particular, impact-resistant.

7. The ballistic layer according to claim 6, wherein the synthetic material mixture comprises polyurethane and/or polyethylene and/or epoxy resin and/or silicon and/or an impact-proof synthetic material and/or an impact-resistant synthetic material.

8. A ballistic multilayer arrangement with an impact side (A) and a back side (B) and a ballistic layer according to claim 1, wherein at least one of the layers is formed by a multilayer fibre layer comprising layers of aramid fibres or comparable fibres, wherein said multilayer fibre layer is, in particular, designed in the form of a woven material or a multilayer woven material.

9. The ballistic multilayer arrangement according to claim 8, wherein at least one of the layers is formed by a plate comprising fine stone or natural stone or ceramic or a ceramic mix, in particular comprising a composite-structure material.

10. The ballistic multilayer arrangement according to claim 8, wherein at least one layer is a spall layer comprising spalls of ceramic or ceramic metal or fine stone or natural stone, which spalls are bound in a matrix.

11. The ballistic multilayer arrangement according to claim 8, wherein at least one layer is formed by a metal plate.

12. The ballistic multilayer arrangement according to claim 8, wherein at least one layer is formed by a highly tenacious synthetic layer.

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13. The ballistic multilayer arrangement according to claim 12, wherein the highly tenacious synthetic layer forms the matrix of the absorption layer.

10 14. The ballistic multilayer arrangement according to claim 8, wherein said arrangement is surrounded by a synthetic cover layer or a fibre-reinforced synthetic braiding layer at least on one of the impact side (A) and the back side (B).

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15. The ballistic multilayer arrangement according to claim 8, wherein in the layer sequence the absorption layer is followed at least on one of its sides by a fibre layer.

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16. The ballistic multilayer arrangement according to claim 8, wherein the arrangement is designed so as to be flexible as a mat or a blanket.

25 17. The ballistic multilayer arrangement according to claim 8, wherein the arrangement is designed as a rigid plate.

18. The ballistic multilayer arrangement according to
30 claim 8, wherein at least one fine stone layer, natural stone layer or ceramic layer, a fibre layer and a metal layer are provided.

19. The ballistic multilayer arrangement according to claim 8, wherein the layer sequence is selected as follows:

- 5 an enveloping layer,
- a ceramic layer, in particular followed by a metal layer,
- a fibre layer and an absorption layer sequence,
- a metal layer.