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(54) **ARMOUR ASSEMBLY**

(57) The present invention provides an armour assembly comprising one or more panels, wherein at least one of the one or more panels comprises a gyroid structure.

The present invention also provides an armoured vehicle, a body-worn armour and a method of manufacturing an armour assembly.

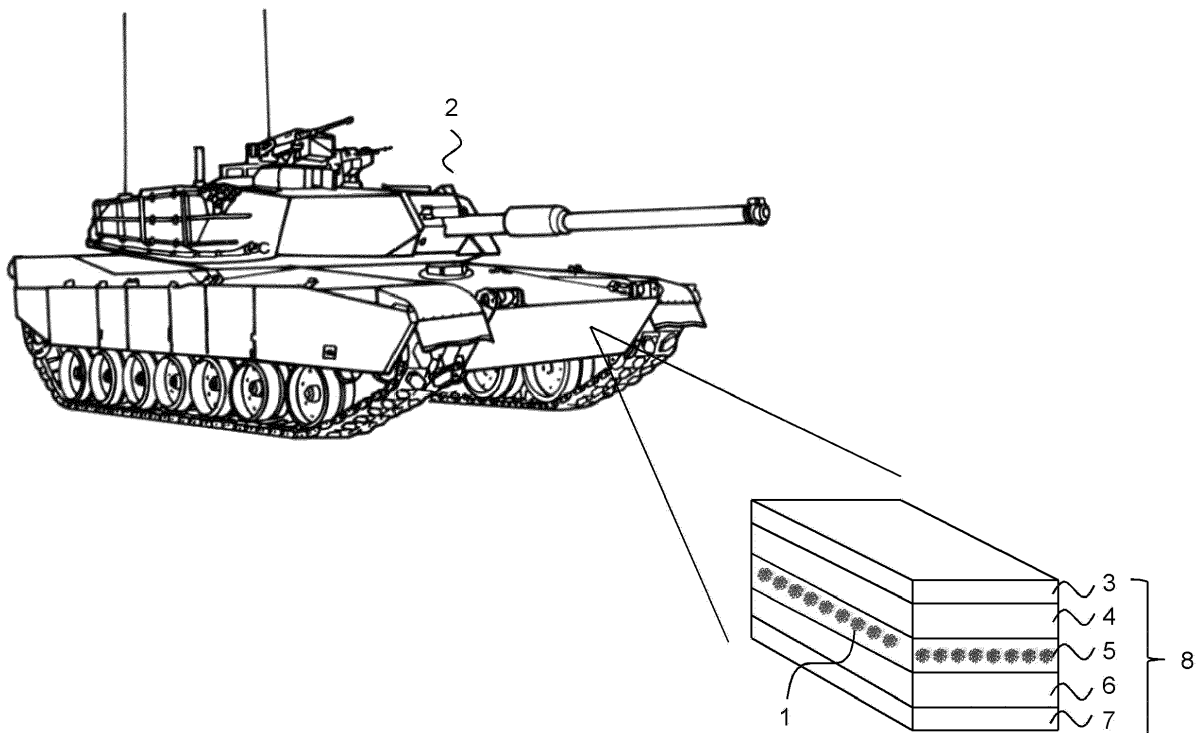


Figure 2

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Description

[0001] The present invention relates to an armour assembly.

[0002] Vehicles, such as military vehicles, sometimes require armour to protect the vehicle and its occupants from harm when the vehicle is in a hostile environment, for example. The type of armour used on a vehicle will primarily depend on the type of anticipated threat, but consideration will also need to be given to the effect of the armour on the vehicle's performance (e.g. the effect on speed and/or manoeuvrability due to the weight of the armour).

[0003] Appliqué armour is routinely used to provide a sacrificial or readily replaceable piece of armour, which defeats certain threats very effectively, but may not provide high levels of general protection from all forms of hazard threats likely to be encountered.

[0004] It is known to use perforated armour plates to protect against kinetic energy projectiles such as ballistic firearm ammunition. Perforated armour comprises a sheet of armour, such as hardened steel, with a plurality of holes therethrough. In addition to being less heavy than solid armour (due to the presence of the holes), perforated armour can provide improved protection against ballistic projectiles. This improved protection at least partly arises from the increase in edged surfaces (i.e. around each hole) that are presented to an incoming ballistic projectile. With an increase in edged surfaces, an incoming ballistic projectile is statistically more likely to impact (or, at least, partially impact) on one of the edged surfaces and thereby experience a higher pressure than it would if it was to impact on a flat surface (such as unperforated armour). The increase of pressure increases the likelihood of the ballistic projectile disintegrating on impact or being deflected and thereby reducing its energy, and thus its ability to penetrate the armour.

[0005] An example of an armour assembly comprising perforated armour is described in EP-A-0209221 (The State of Israel Ministry of Defence Rafael - Armament Development Authority). The armour assembly of EP-A-0209221 is specifically designed for armoured vehicles and comprises a perforated armour plate mounted to a conventional armour plate and spaced therefrom.

[0006] As mentioned above, whilst the addition of armour increases a vehicle's defences against ballistic projectiles, the added weight can impair the vehicle's ability to manoeuvre and travel at its optimal or preferred speed or acceleration rate, even when lighter perforated armour is used. This is a particular problem when considering vehicles that may be travelling in and out of known safe areas where no or less protection is required, or when travelling in areas where it is undesirable to compromise the vehicle's speed, acceleration or manoeuvrability. In these cases, the armour must be removed from the vehicle which is an onerous task that requires the personnel to be in possession of the appropriate tools.

[0007] It is an object of the present invention to provide

an armour assembly that overcomes the problems associated with the prior art.

[0008] According to a first aspect of the present invention, there is provided an armour assembly comprising one or more panels, wherein at least one of the one or more panels comprises a gyroid structure.

[0009] Gyroid structures tend to be lightweight and of low density yet have a high tensile strength. By incorporating such a structure into an armour assembly, the armour assembly can maintain its property of high resistance to penetration and blast, while being made more lightweight to enable a vehicle to travel faster or a person wearing the armour assembly to be less prone to fatigue.

[0010] The gyroid structure may be manufactured using a three-dimensional image forming apparatus.

[0011] There may be at least one panel disposed adjacent to the panel comprising the gyroid structure.

[0012] The panel disposed adjacent to the panel comprising the gyroid structure may comprise an armour plate. Alternatively, the panel disposed adjacent to the panel comprising the gyroid structure may comprise Kevlar™.

[0013] The armour assembly may comprise the primary armour of a vehicle.

[0014] The gyroid surface can be trigonometrically approximated by the equation:

$$\sin x \cos y + \sin y \cos z + \sin z \cos x = 0$$

[0015] The gyroid structure may be manufactured from one of a metal, a metal alloy, a composite, a polymer, an elastomer, metalloid and a ceramic. The metalloid may be carbon, such as graphene.

[0016] The gyroid structure may be used to turn bi-dimensional materials, such as graphene, into a three-dimensional structural material having low density and yet retaining high tensile strength.

[0017] The thickness of the surface of the gyroid structure may be between 0.5 mm and 10 mm. Preferably, the thickness may be between 1 mm and 5 mm. Even more preferably, the thickness may be 2 mm.

[0018] The gyroid structure may be encapsulated in an encapsulating structure. The encapsulating structure may be formed using the three-dimensional printing apparatus.

The gyroid structure may comprise a plurality of cavities which may comprise a filler material. The filler material may comprise a particulate, liquid or foam.

[0019] The armour assembly may further comprise brackets for coupling the armour assembly to the body of a vehicle, vessel or craft. The brackets may be manufactured using the three-dimensional image forming apparatus. The gyroid structure, brackets and encapsulating structure may be formed as part of the same processing step.

[0020] According to a second aspect of the present

invention, there is provided a body-worn armour comprising the armour assembly of the first aspect.

[0021] According to a third aspect of the present invention, there is provided an armoured vehicle having a main body, wherein the main body comprises the armour assembly according to the first aspect. The armour assembly according to the first aspect may be coupled to the main body of the vehicle using brackets.

[0022] According to a fourth aspect of the present invention, there is provided a method of manufacturing an armour assembly, comprising three-dimensionally printing at least one panel having a gyroid structure.

[0023] The method may comprise encapsulating the gyroid structure.

[0024] The method may further comprise attaching the panel having the gyroid structure to at least one further panel.

[0025] The method may comprise forming brackets on the panel having the gyroid structure.

[0026] Embodiments of the invention are further described hereinafter with reference to the accompanying drawings, in which:

Figure 1 shows a perspective view of a gyroid structure;

Figure 2 shows a perspective view of an armoured vehicle according to an embodiment of the present invention;

Figure 3 shows a perspective view of an armoured vehicle according to another embodiment of the present invention; and

Figure 4 shows a perspective view of an armoured vehicle according to another embodiment of the present invention.

[0027] Embodiments of the present invention provide an armour assembly comprising a gyroid structure. This tends to reduce the weight of the armour assembly without compromising its ballistic or blast protection for occupants of a vehicle, vessel or craft. The armour assembly can also be incorporated into a body-worn armour such a bulletproof or stab vest.

[0028] Figure 1 shows a perspective view of a gyroid structure 1. The gyroid structure 1 separates space into two oppositely congruent labyrinths of passages. The gyroid structure 1 has space group Ia3d. Channels run through the gyroid labyrinths in the (100) and (111) directions; passages emerge at 70.5 degree angles to any given channel as it is traversed, the direction at which they do so gyrating down the channel, giving rise to the name "gyroid". The gyroid structure 1 contains neither straight lines nor planar symmetries.

[0029] According to some embodiments, the gyroid structure 1 may be printed using a 3D printer.

[0030] The gyroid structure 1 is formed of graphene. The thickness of the surface of the gyroid structure is 2 mm. In other embodiments, the gyroid structure 1 may be formed of any suitable material, and has a thickness

of between 0.5 mm and 10 mm.

[0031] Figure 2 shows an armoured vehicle 2 having a main body comprising a hull and a turret. The main body comprises an armour assembly 8, formed from a series of armour panels 3-7. Each panel 3-7 may have a thickness of between 100 mm and 500 mm. At least one of the panels 3-7 is an armour plate. Each panel 3-7 comprises an armour material. Preferably, the armour material in each panel 3-7 is different to the armour material in the other panels 3-7.

[0032] In the embodiment of Figure 2, the armour assembly 8 has 5 panels 3-7. Here, the first panel 3 may be, for example, an armour plate made of steel. The second panel 4 may be, for example, formed of a honeycomb structure made from ceramic. The third panel 5 may, for example, be filled with the gyroid structure 1 shown in Figure 1. The fourth panel 6 may be, for example, filled with a liquid. The fifth panel 7 may be, for example, filled with a foam.

It would be appreciated that the panels 3-7 could be arranged in any order and could be formed of different armour materials than those described above. For example, the first panel 3 may instead comprise the gyroid structure 1.

[0033] The armour material of at least one of the panels 5 comprises the gyroid structure 1 shown in Figure 1. The panel 5 having the gyroid structure 1 may be encapsulated. In some embodiments, the gyroid structure 1 is encapsulated using the same material as used to form the gyroid structure 1. For example, the gyroid structure 1 and encapsulating structure may be formed in a single three-dimensional printing process. Armour material of the other panels 3-7 in the armour assembly 8 is selected from known armour materials.

The gyroid structure 1 includes cavities. In some embodiments, the cavities are filled with a filler. Use of the filler tends to provide an improved armour effect. The fillers may include liquids (such as shear thickening fluid and water), foams and particulates (such as sand, metals and uncured 3D printing material).

[0034] Although the armour assembly 8 shown in Figure 2 is a section through the front of the hull of the vehicle 2, the armour assembly 8 may form the main body of any part of the vehicle 2. For example, the armour assembly 8 may form the top surface of the turret in order to protect the occupants from aerial attack or indirect fire. The armour assembly 8 may form the rear of the hull to protect the engine compartment. The armour assembly 8 may form the side skirts of the vehicle 2 to protect the tracks and bogies.

[0035] Additionally, the armour assembly 8 according to some embodiments is applied to the vehicle 2 as appliqué armour. Here, the armour assembly 8 includes brackets for attaching the armour assembly 8 to the main body of the vehicle 2. In some embodiments, the gyroid structure 1 (and, in some embodiments, the encapsulating structure) and brackets are formed in a single three-dimensional printing process. In other words, due to the

gyroid structure 1 being 3D printed directly from a computer aided design (CAD) file, a surface shell (i.e. an encapsulating structure) surrounding the gyroid structure 1 with built-in brackets can be incorporated in to the CAD file and printed as one unit.

[0036] Figure 3 shows another embodiment of the present invention. Here, the armour assembly 8 includes only two panels 4, 5. One of the panels 5 comprises the gyroid structure 1 shown in Figure 1. Brackets may be fixed to one of the outer panels 4, 5 in order to couple the armour assembly 8 to the vehicle 2. Alternatively, the armour assembly 8 may form the primary armour of the vehicle 2.

[0037] Figure 4 shows another embodiment of the present invention. Here, the armour assembly 8 includes only a single panel 5. The panel 5 comprises the gyroid structure 1 shown in Figure 1. As explained above, the gyroid structure 1 may be encapsulated in a material different to that of the gyroid structure 1. Alternatively, the gyroid structure 1 may be encapsulated in the same material as the gyroid structure 1. The panel 5 may further include brackets for fixing the armour assembly 8 to the vehicle 2. Alternatively, the armour assembly 8 may form the primary armour of the vehicle 2.

[0038] It would be readily understood that Figures 3 and 4 show only examples of an armour assembly 8 structure, and in other embodiments the armour assembly 8 includes more than the number of panels 3-7 shown in these Figures.

[0039] According to other embodiments, instead of a tracked armoured vehicle 2, the armour assembly 8 according to the present invention may be incorporated into the main body of a wheeled vehicle, a vessel or an aircraft, such as a ship or helicopter.

[0040] In some embodiments, instead of a vehicle 2, the armour assembly 8 is used in a garment such as a bulletproof vest or a stab vest. In some of these embodiments, the armour material of at least one of the armour panels 3-7 comprises Kevlar™.

[0041] It will be appreciated that the above-described embodiments are purely illustrative and are not limiting on the scope of the invention. Other variations and modifications will be apparent to persons skilled in the art upon reading the present application.

[0042] Moreover, the disclosure of the present application should be understood to include any novel features or any novel combination of features either explicitly or implicitly disclosed herein or any generalization thereof and during the prosecution of the present application or of any application derived therefrom, new claims may be formulated to cover any such features and/or combination of such features.

Claims

1. An armour assembly comprising one or more panels, wherein at least one of the one or more panels com-

prises a gyroid structure.

2. The armour assembly according to claim 1, wherein the thickness of the surface of the gyroid is between 0.5 mm and 10 mm.
3. The armour assembly according to claim 1 or claim 2, wherein the gyroid structure is encapsulated.
4. The armour assembly according to any one of the preceding claims, wherein the gyroid structure is manufactured using a three-dimensional image forming apparatus.
5. The armour assembly according to any one of the preceding claims, wherein there is at least one panel disposed on the panel comprising the gyroid structure.
6. The armour assembly according to claim 5, wherein the panel disposed adjacent to the panel comprising the gyroid structure comprises an armour plate.
7. The armour assembly according to claim 5, wherein the panel disposed adjacent to the panel comprising the gyroid structure comprises Kevlar™.
8. The armour assembly according to any one of the preceding claims, wherein the gyroid structure is manufactured from one of a metal, a metal alloy, a metalloid, a composite, a polymer, an elastomer, carbon and a ceramic.
9. The armour assembly according to any one of the preceding claims, wherein the gyroid structure comprises a plurality of cavities which comprise a filler material.
10. The armour assembly according to claim 9, wherein the filler material comprises a particulate, foam or liquid.
11. The armour assembly according to any one of the preceding claims, further comprising brackets for coupling the armour assembly to the body of a vehicle, vessel or craft.
12. The armour assembly according to claim 11, wherein the brackets are manufactured using the three-dimensional image forming apparatus.
13. A body-worn armour comprising the armour assembly according to any one of claims 1 to 10.
14. An armoured vehicle having a main body, wherein the main body comprises the armour assembly according to any one of claims 1 to 12.

15. A method of manufacturing an armour assembly, comprising three-dimensionally printing a first panel having a gyroid structure.

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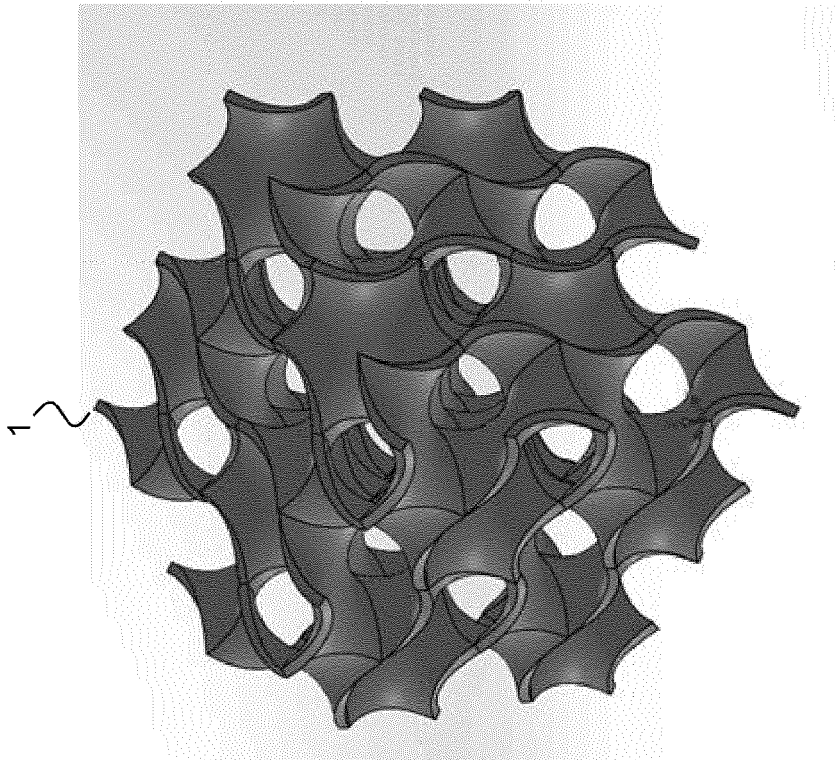


Figure 1

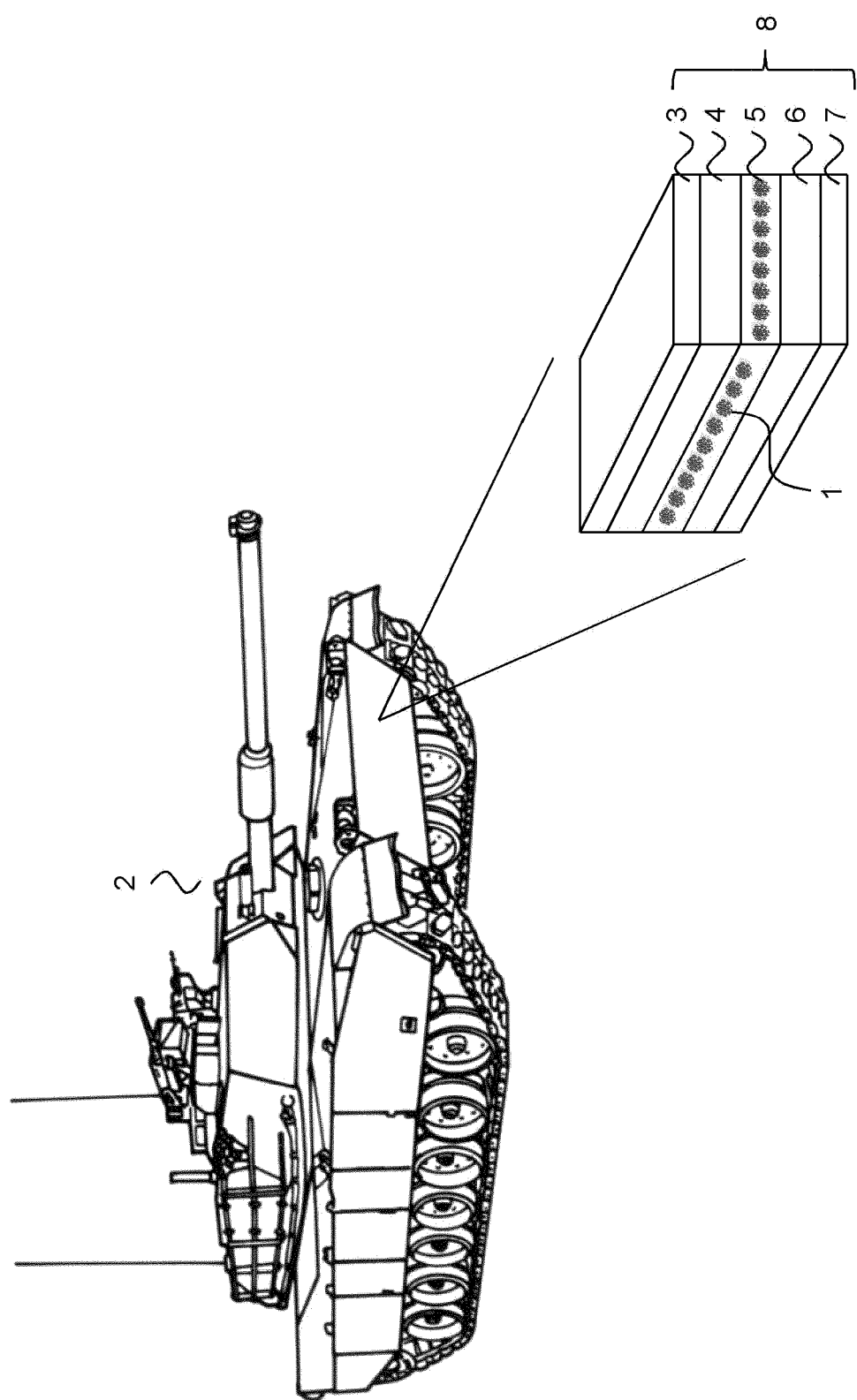


Figure 2

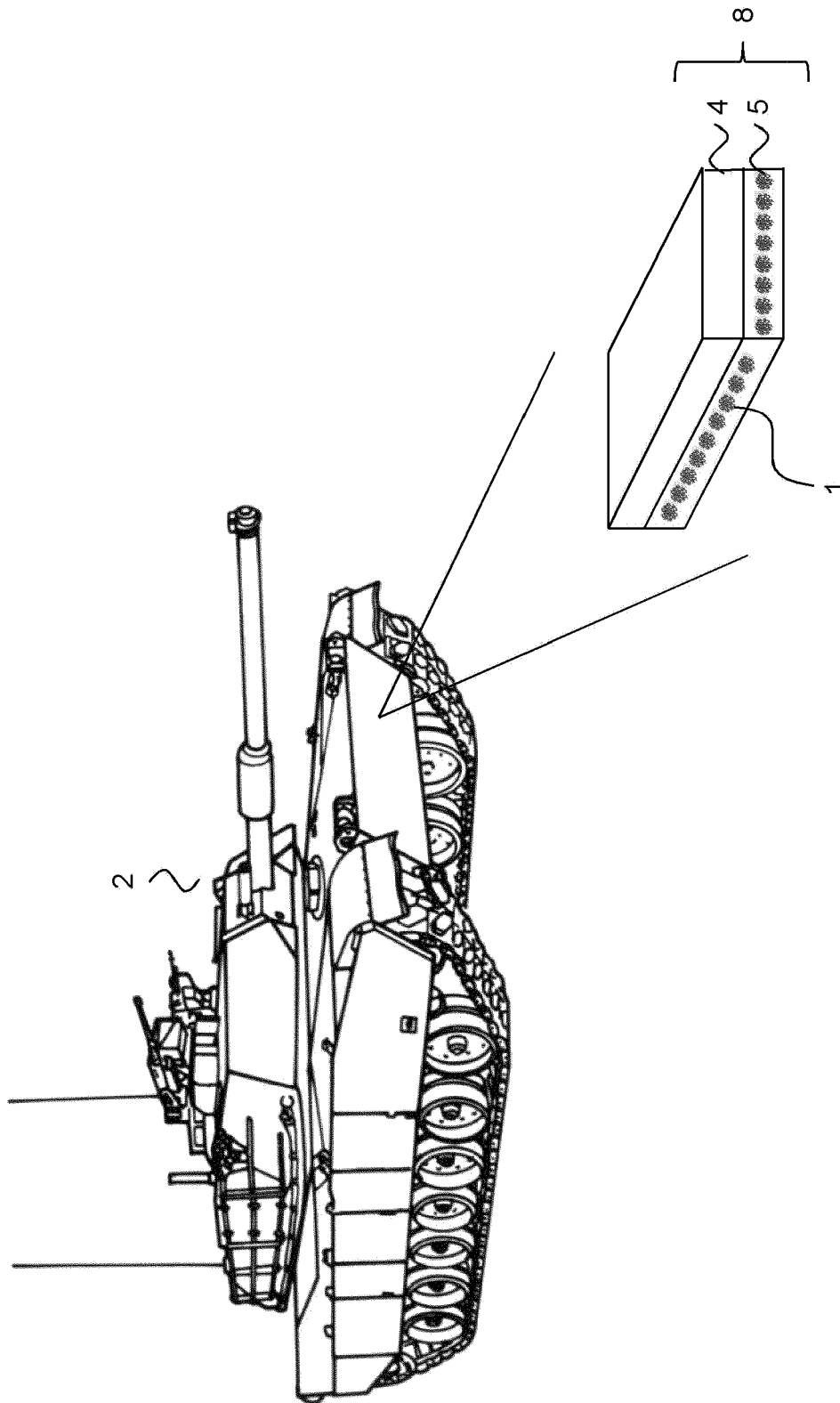


Figure 3

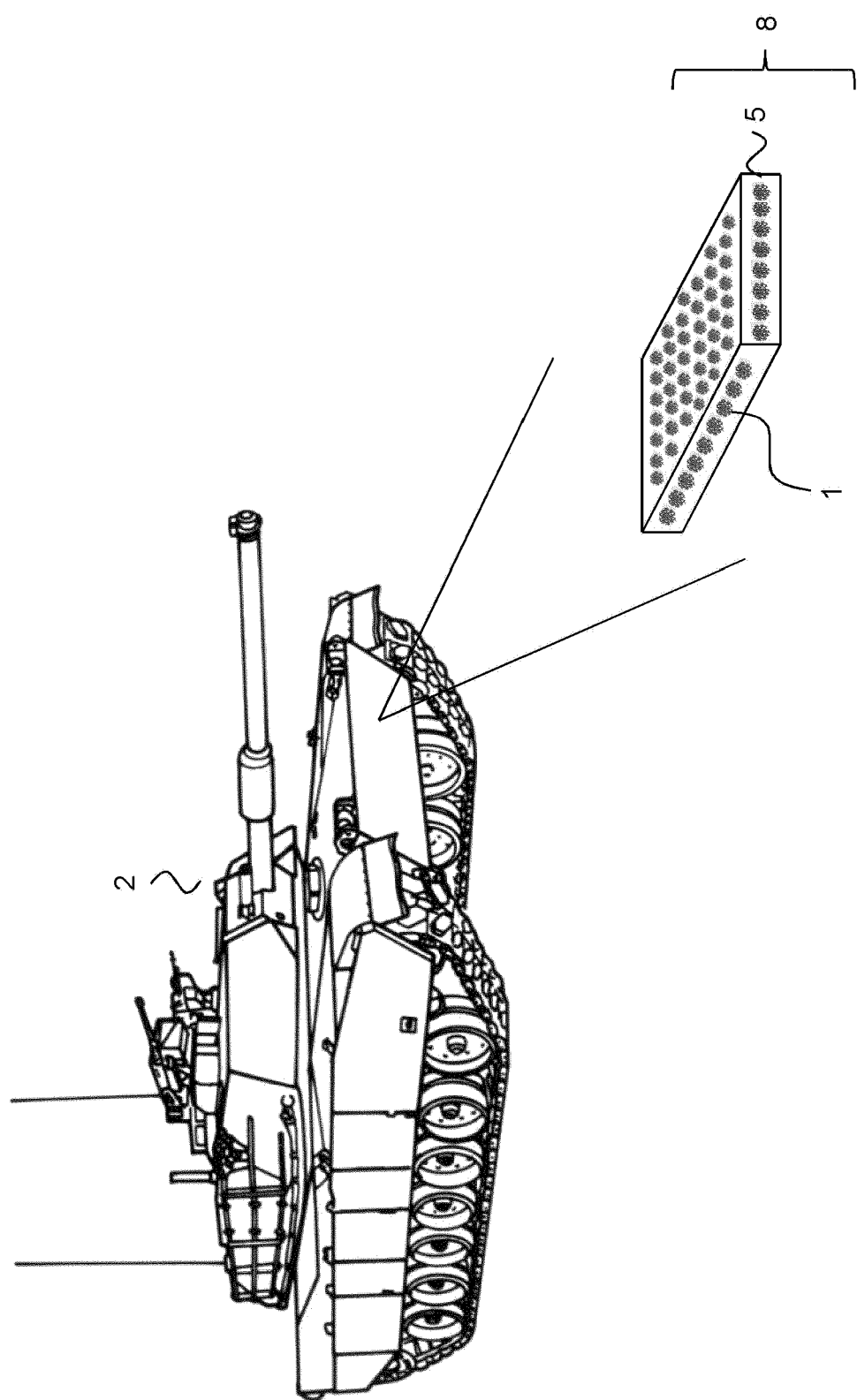


Figure 4



EUROPEAN SEARCH REPORT

Application Number
EP 17 19 7575

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A	US 9 116 428 B1 (JACOBSEN ALAN J [US] ET AL) 25 August 2015 (2015-08-25) * abstract * * column 1, lines 13-24 * * figures 1-11 *	1-15	INV. F41H5/02
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A,D	EP 0 209 221 A1 (ISRAEL STATE [IL]) 21 January 1987 (1987-01-21)	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F41H
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 16 February 2018	Examiner Menier, Renan
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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