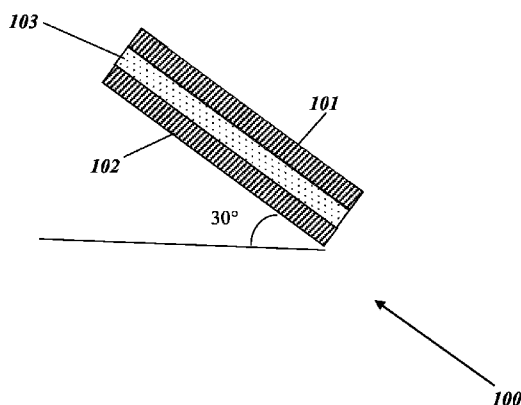




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(54) Title: REACTIVE ARMOUR



**Fig. 1**

(57) Abstract: A rigid or flexible protection element for reactive protection against shaped charge warheads and kinetic energy projectiles comprises a metallic or ceramic powder dispersed within a matrix of plastic explosive and a binder.



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## REACTIVE ARMOUR

### Field of the Invention

The present invention relates to the field of reactive armour. More particularly, the invention relates to a shapeable material for reactive surfaces and to a process for its preparation.

### Background of the Invention

Reactive armour has been employed in the art for quite some time to defend against attacks by a variety of anti-tank charges (which are used against all kinds of armoured vehicles) and to reduce the damage done to the vehicle being protected. It is most effective in protecting against shaped charge warheads and kinetic energy penetrators.

An element of explosive reactive armour consists of an explosive layer sheet or slab of high explosive sandwiched between two plates, typically metal ones. When hit by anti-armour threat, either Shaped Charge warheads or Long Rod penetrators, the explosive detonates, forcibly driving the metal plates apart to damage the penetrator. Against a shaped charge, the projected plates disrupt the metallic jet penetrator, effectively providing a greater path-length of material to be penetrated. Against a kinetic energy penetrator, the projected plates serve to deflect and break up the rod.

The disruption is attributed mainly to the following mechanism. Since the plates are angled with respect to the impact direction of shaped charge warheads, as the plates move outwards the impact point, the plates move continuously over time, requiring the jet to cut through additional fresh plate material. This effect actually increases the effective plate thickness during the impact.

A complication to the use of reactive armour is the hazardous risks to the surroundings – dismounted troops or vehicles, due to fragments or moving plates emanating from the explosive detonation. Another complication is that conventional reactive armour is made of flat plates and is not suited to protect non-planar surfaces. It would therefore be highly desirable to provide new reactive armour that reduces the collateral damage effects to the surroundings and which can also be easily applied to non-planar surfaces.

It is an object of the present invention to provide a novel reactive component of reactive armour, which maintains its efficacy against threats while reducing the damage to the surroundings, as compared to prior art reactive armours.

It is another object of the invention to provide such an energetic component of reactive armour, which can be applied to non-planar surfaces.

It is yet another object of the invention to provide reactive armour employing the novel energetic component.

Other objects and advantages of the invention will become apparent as the description proceeds.

#### Summary of the Invention

The invention relates to a rigid or flexible protection element for reactive protection against shaped charge warheads and kinetic energy projectiles, comprising a metallic or ceramic powder dispersed within a matrix of plastic explosive and a binder, which can be utilized as a stand-alone protection element or as a part of protection system such as reactive cassette.

In one embodiment, the protection element of the invention is configured to be fully detonated upon impact by a shaped charge warhead or a kinetic energy projectile.

In another embodiment of the invention the protection element is configured to be only locally detonated upon impact by a shaped charge warhead or kinetic energy projectile.

The reactive element of the invention can have a distribution of the metallic powder or ceramic powder within the matrix, which is homogeneous, or one which is non-homogeneous.

The invention also encompasses a combination of several reactive elements as described above, which differ in the amount of the metallic or ceramic powder dispersed within the matrix of plastic explosive and binder.

In another aspect the invention is directed to a protection element in which the explosive is homogeneously dispersed throughout the entire area of the cross section and in a further embodiment of the invention there is provided a protection element in which the explosive is dispersed in different concentrations throughout the entire area of the cross section. Moreover, in another embodiment of the invention the protection element is designed such that the explosive is dispersed only in partial area of the cross section.

The invention further provides a reactive element, which is not planar in shape.

In one embodiment of the invention the metal powder provided in the reactive element is a tungsten powder. According to one embodiment the median diameter of the tungsten particles is approximately 120  $\mu$ . In another embodiment of the invention the metal powder is a tungsten carbide powder, and in yet another embodiment of the invention the mean diameter of the tungsten carbide particles is approximately 80  $\mu$ .

While the invention is not limited to any specific explosive, according to one embodiment of the invention the plastic explosive material is selected from Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) and 1,3,5-Trinitroperhydro-1,3,5-triazine (RDX).

Similarly, the solid particles can have a variety of shapes, and according to one embodiment of the invention the particles have an essentially round shape.

Binders suitable for use with the invention will be recognized by the skilled person. According to one embodiment of the invention the binder is selected from among Hydroxyl-terminated polybutadiene (HTPB) and Polydimethylsiloxane (PDMS).

The invention further encompasses structure protected by a reactive layer according to the invention, including but not limited to vehicles and buildings. According to one embodiment of the invention at least part of the protected surface is rounded or wavy.

### Brief Description of the Drawings

In the drawings:

Fig. 1 schematically illustrates typical reactive armour.

### Detailed Description of the Invention

Fig. 1 schematically illustrates a typical reactive armour 100, which consists of upper metal plate 101, bottom metal plate 102, and explosive layer 103, sandwiched between them. A typical angle at which the reactive armour is positioned is  $30^\circ$  relative to the ground. According to the invention this set-up can be maintained, if desired, but the intermediate layer of explosive material can also be used as a stand-alone element without adding the metal plates, while maintaining the efficiency of protection. This is particularly important when it is desired to protect a non-planar (e.g. curved) surface such as a tank turret.

A typical reactive component according to the invention contains (23-33% on a weight basis) of an explosive material, (64-74%wt) of a particulate

solid and (2-4%wt) of a binder, which may be, for instance, HTPB, or a silicon-based or other binder. Binders are well known in the art and, therefore, are not discussed herein in detail, for the sake of brevity. An illustrative example is a reactive material made of 28%wt HMX explosive, 69%wt of tungsten carbide powder with a median diameter of 80 $\mu$ m and 3% of HTPB. A typical thickness of the resulting reactive layer is in the range of 9-30 mm.

It should be noted that the amount of particulate material to be used according to the invention, as well as the size of the particles, are important. It has been found that a diameter of between 45-180 $\mu$ m provides a suitable result, although the invention is not limited to such sizes, which are provided for the purpose of illustration. The particles can be rounded in shape or can be irregular, in which case the effective diameter is referred to.

The reactive layer can be prepared by a simple process, which involves mixing performed in a Planetary-type mixers at 60 rpm and temperature of 50-60 $^{\circ}$ c. The explosive dough produced by mixing is injected in vacuum conditions followed by pressing to explosive sheets in the required thickness. After pressing, the material is cured in an oven at 55 $^{\circ}$ C  $\pm$ 5 $^{\circ}$ C. For safety considerations, all the procedures are preferably performed from a remote control room.

### Examples

All the reactive layers prepared according to the following examples were tested in a standard test using a 30° support and an RPG-7 as the charge. All reactive layers gave results comparable to those of the prior art.

#### Example 1

HMX Class 3 (19%wt), HMX Class 5 (9%wt) was employed, together with particles of tungsten carbide (69%wt) and HTPB up to 100%wt, to prepare a reactive layer. The particle size distribution of the tungsten carbide was  $d_{10}=50\ \mu\text{m}$ ;  $d_{50}=80\ \mu\text{m}$ ;  $d_{90}=130\ \mu\text{m}$  and the particles were rounded in shape. Care was taken to obtain a substantially homogeneous distribution of the particles in the mixture. The equipment used was a high shear mixer and an injector and hydraulic press. The process involved the following steps: Raw materials mixing followed by injection and dough pressing to get sheet with appropriate thickness. Final steps are curing and sheet cutting.

#### Example 2

Example 1 was repeated, with different particles. HMX Class 3 (16%wt), HMX Class 5 (7%wt) were employed, together with tungsten particles (73%wt) and HTPB up to 100%wt, to prepare a reactive layer. The particle size distribution of the tungsten was  $d_{10}=90\ \mu\text{m}$ ;  $d_{50}=120\ \mu\text{m}$ ;  $d_{90}=170$

$\mu\text{m}$  and the particles were rounded in shape. Care was taken to obtain a substantially homogeneous distribution of the particles in the mixture. The equipment used was a high shear mixer and an injector and hydraulic press. The process involved the following steps: Raw materials mixing followed by injection and dough pressing to get sheet with appropriate thickness. Final steps are curing and sheet cutting.

### Example 3

Example 2 was repeated with the following parameters: RDX Class 1 (23%wt), RDX Class 5 (10%wt) were employed, together with particles of tungsten (64%wt) and HTPB (3%wt), to prepare a reactive layer. The median particle size of the tungsten was  $d_{50}=80 \mu\text{m}$ .

All the above descriptions and examples have been provided for the purpose of illustration and are not intended to limit the invention in any way, except as provided for by the appended claims. Many different metal and ceramic materials can be employed, a large range of diameters can be used, and many suitable binders can be utilized, which are known to the skilled person, without exceeding the scope of the invention.

Additionally, the explosive of the type described herein may be beneficially used in other applications, where formability into curved structures and

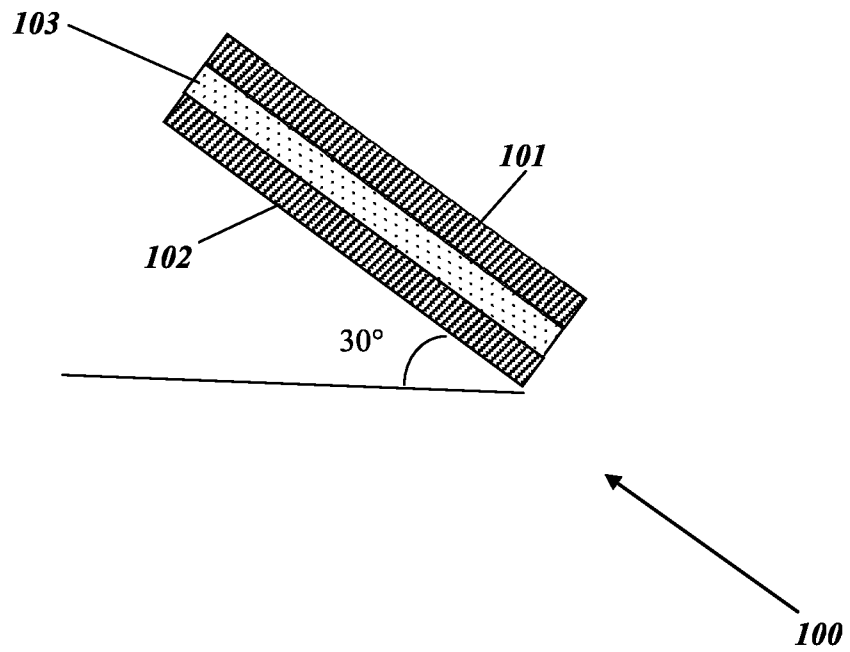
minimum collateral damage are important. One such application is the countermeasure of active protection system against shaped-charge missiles warhead or rockets and kinetic penetrators. In the prior art, these countermeasures have employed barrel-launched projectiles, spherical or linear explosively-formed projectiles, fragmentation explosive charge, or blast charge, all of which require very precise aiming and timing, and/or exhibit highly intolerable collateral damage. Use of the explosive according to the invention in such countermeasure will assure neutralization of the threat under easier precision constraints of aiming and timing, with minimal collateral damage. Another application of the invention is in warheads of precision-guided munitions, which are meant to assure minimal collateral damage.

CLAIMS

1. A rigid or flexible protection element for reactive protection against shaped charge warheads and kinetic energy projectiles, comprising a metallic or ceramic powder dispersed within a matrix of plastic explosive and a binder.
2. The reactive element as claimed in claim 1 when utilized as a stand-alone protection element.
3. The reactive element as claimed in claim 1 when utilized as a part of protection system such as reactive cassette.
4. A protection element per claim 1 which is fully detonated upon impact by shaped charge warhead or kinetic energy projectile.
5. A protection element per claim 1 which is only locally detonated upon impact by shaped charge warhead or kinetic energy projectile.
6. The reactive element as claimed in claim 1 in which the distribution of the metallic powder or ceramic powder within the matrix is homogeneous.
7. The reactive element as claimed in claim 1 in which the distribution of the metallic powder or ceramic powder within the matrix is non-homogeneous.
8. A combination of several reactive elements, each one as claimed in claim 1 which differ in the amount of the metallic or ceramic powder dispersed within the matrix of plastic explosive and binder.

9. A protection element per claim 1 in which the explosive is homogeneously dispersed throughout the entire area of the cross section.
10. A protection element per claim 1 in which the explosive is dispersed in different concentrations throughout the entire area of the cross section.
11. A protection element per claim 1 in which the explosive is dispersed only in partial area of the cross section.
12. A reactive element as claimed in claim 1, which is not planar in shape.
13. A reactive element as claimed in claim 1, wherein the metal powder is a tungsten powder.
14. A reactive layer according to claim 3, wherein the median diameter of the tungsten particles is approximately 120  $\mu$ .
15. A reactive layer as claimed in claim 1, wherein the metal powder is a tungsten carbide powder.
16. A reactive layer according to claim 5, wherein the mean diameter of the tungsten carbide particles is approximately 80  $m\mu$ .
17. A reactive layer according to claim 1, wherein the plastic explosive material is selected from HMX and RDX.
18. A reactive material according to claim 1, wherein the particles have an essentially round shape.

- 19.A reactive material according to claim 1, wherein the binder is selected from among HTPB and PDMS.
- 20.A structure protective by a reactive layer according to claim 1.
- 21.A structure according to claim 10, which is a vehicle.
- 22.A structure according to claim 10, which is a building.
- 23.A structure according to claim 10, wherein at least part of the surface is rounded or wavy.



*Fig. 1*

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL2017/051390

A. CLASSIFICATION OF SUBJECT MATTER IPC (2018.01) F41H 5/007, C04B 14/32		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) IPC (2018.01) F41H 5/007, C04B 14/32, F41H 7/02, B22F 1/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Databases consulted: Esp@cenet, Google Patents, Orbit Search terms used: EXPLOSIVE, REACTIVE, ARMOR, ARMOUR, BINDER, PLASTIC, POWDER, CERAMIC, METALLIC, TUNGSTEN, ALLOY, CARBIDE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
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* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
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Date of the actual completion of the international search 27 Mar 2018	Date of mailing of the international search report 27 Mar 2018	
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	Authorized officer COHAY Mattan  Telephone No. 972-2-5651611	

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