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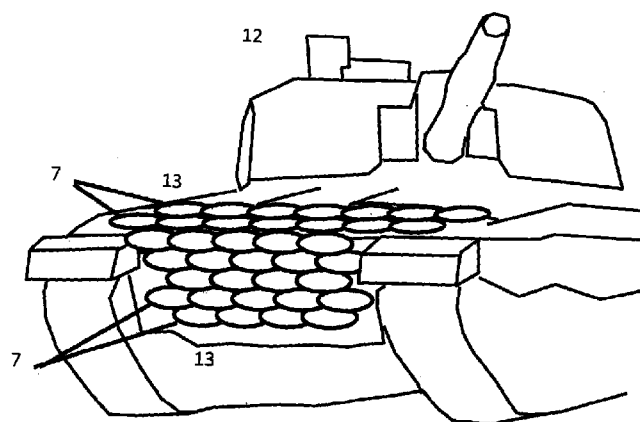


Figure 8

(57) Abstract: A method and apparatus are provided for protecting a target or vehicle from shaped charge jet weapons which project a narrow jet of high velocity metal. The jet is disrupted by a spinning armour element, typically a disk, rotating at sufficient speed as to cause the jet to be disrupted. Because the jet is disrupted, a secondary layer of armour is able to absorb the jet.



Method and apparatus for protecting against high velocity weapons

The present invention relates to active armour for mitigating high velocity weapons such as shaped charge jets and kinetic energy penetrator weapons, and is particularly applicable to the field of armoured vehicles.

A known weapon for penetrating thick vehicle armour is the shaped charge jet, which is provided in some warheads and rocket propelled grenades. This device consists of an explosive charge uniformly surrounding a cone of metal foil – typically copper but sometimes other materials such as aluminium. As the copper foil collapses in a symmetrical manner, the copper converges at the axis of the cone, and is ejected at extremely high velocities along that same axis, typically at speeds of 5 to 10km per second. Manufacturing armour with a thickness suited to protecting against shaped charges is often impractical.

A known way to mitigate this kind of weapon is to provide a sheet of explosive material sandwiched between metal sheets (also known as a cassette), arranged in front of the armour at an oblique angle to the expected threat direction. The jet of copper from the shaped charge ignites an explosive chain reaction down and along the explosive sheet, and this extremely rapidly causes the metal sheets to be thrown obliquely into the path of the incoming jet. As the jet is exposed to additional material interfering with its path, this causes the jet to become uneven, which makes it far less effective at penetrating the rest of the armour. This form of armour is often referred to as explosive reactive armour (ERA).

A problem with this type of armour is that once the explosive film has been ignited it is useful for a very short period of time, and a second shaped charge weapon fired even a short period of time later (E.g. 1 micro second) would be free to impact directly on the main armour without being disrupted in the manner described. In fact a particular form of shaped charge weapon known as a tandem shaped charge has been developed for this purpose.

It is an object of the present invention to overcome the above problem.

According to one aspect of the present invention there is provided an armour panel comprising:

A base armour layer arranged substantially in a plane, for resisting military bullets, missiles and/or shells directed from an outboard direction; and

An active armour layer for disrupting a shaped charge jet of a shaped charge jet warhead or rocket propelled grenade, the active armour layer being disposed outboard of the base armour layer;

wherein the active armour layer comprises:

An array of armour elements, arranged in a substantially adjacent or overlapping fashion; and

Drive means for spinning at least any one of the armour elements about a respective axis for disrupting a shaped charge jet of a shaped charge jet warhead or of a rocket propelled grenade.

The armour elements in preferred embodiments are armour plates, in these embodiments the respective axis being substantially perpendicular to the plane of the base armour layer.

Note that the ground engaging wheels of armoured ground vehicles do not constitute a means for disrupting a shaped charge jet. To disrupt a shaped charge jet requires moving mass into the path of the shaped charge jet at a rate in the order of at least within a few orders of magnitude of the rate of moving mass of the shaped charge jet, which itself travels at a speed of around 5km per second or more. Generally this will involve spinning the plates at at least 5000 revolutions per minute (rpm) preferably at least 10,000 rpm, more preferably at least 15,000 rpm, and in typical embodiments at at least 20,000 rpm, and potentially at at least 40,000 rpm.

Using a comparatively thick plate, with a tip thickness of 5mm, the tip of the plate generally will require a tip speed of at least around 1000m/s. However with a thinner tip thickness of 1mm, the tip speed should generally be around 5000m/s (which would either require substantially instantaneous acceleration of the disk, or else operating continuous in a vacuum due to energy losses due to air friction at these speeds). I.e. the thickness of plate at any given radial position in mm, multiplied by its circumferential speed in m/s should be greater than around 5000mm.m/s. Clearly, the ground engaging wheels of armoured vehicles do not come close to this range.

The term 'substantially adjacent or overlapping fashion' covers various plate armour arrangements, however as an attacking angle of an incoming warhead or RPG (rocket propelled grenade) may be assumed to only occur in a limited range of oblique angles, it may be possible to allow a gap between the plates as seen from other directions. Additionally, small gaps in the protection may be tolerated by some users, and therefore overlapping the plates is not essential.

The term "substantially perpendicular to the plane of the base armour" covers exactly perpendicular as well as variations such as up to 20 degrees therefrom, however variations typically will be in the range 0 to 1 degrees. The base armour is generally in a plane (or multiple parts may be respective planes), and the axis of rotation is generally substantially perpendicular to the plane of the adjacent base armour, but in an extreme example the axis may be at an angle from that (e.g. local) plane, such as at 40 degrees from the plane. Typically the angle may be in the range 0-20 degrees, but in an extreme case 0-70 degrees.

Typically the armour plates are disks, each disk having an axial thickness that tapers from a maximum axial thickness substantially at the axis of the disk, to a minimum axial thickness substantially around the circumference of the disk. This is useful to enable the disk to be spun to higher speeds without disintegrating from centripetal forces, than is possible with a flat disk, as well as minimising air friction.

Optionally the armour panel comprises a drive shaft connected to each armour plate and comprises for each armour plate, means to drive the drive shafts to maintain the armour plates spinning for disrupting such a shaped charge jet.

This has the advantage that the armour plates can be effective continuously over a period of time as required, rather than needing to be suddenly accelerated in the event of a threat (inbound projectile or shaped charge jet).

Alternatively the armour panel comprises means respectively coupled to (or more specifically coupled substantially around a circumference of, or face of) each armour plate, to provide substantially instantaneous acceleration for disrupting such a shaped charge jet.

This has the advantage that the armour plates do not need to be maintained rotating at high speed. Instead, explosive charges may be used to accelerate the armour plate instantaneously, and guides may be provided to control the direction of motion. For example a number of pistons may be provided around the periphery of the armour plate containing explosive to drive a sudden acceleration of the rotation of the plate. In such embodiments the explosive may be substituted by compressed gas. As an alternative to pistons or other guides, the plate may be in the form of a pelton wheel or similar structure such that the explosive or compressed gas may be directed to its baffles. Alternatively the plate may comprise nozzles arranged around its periphery (in the form of a Katherine wheel), disposed tangentially so as to suddenly accelerate the rotation of the plate, and powered either by combustion fuel exhaust or compressed gas or similar.

The armour plates are preferably arranged in respective housings, each arranged to contain shrapnel arising from the disintegration of the armour plate, to prevent damage to neighbouring armour plates. This avoids the possibility of a chain reaction whereby shrapnel originating from the disintegration of each armour plate initiates the disintegration of neighbouring armour plates.

Preferably each armour plate is provided with respective drive means. The drive means may be a motor (electric motor, or positive displacement fluid driven, or non-positive displacement fluid driven (e.g. pelton wheel), or other methods). Alternatively the drive means may provide for substantially instantaneous acceleration (explosives in pistons, rocket nozzles, or the wheel may substantially consist of a substantially unloaded, coiled and tensioned spring, such that it provides its own drive means).

Optionally the armour plates are arranged on fluid dynamic bearings, such as fed with oil. This has the advantage of withstanding the very considerable torque generated if the panel is rotated (e.g. when the vehicle turns a corner or rides over uneven ground) while the armour plates(s) are rotating at speed. The fluid dynamic bearings generally will include two radial load bearings arranged on a drive shaft at different axial positions, and an axial load bearing.

Radial load bearings include an inner bearing in the shape of a cylinder with a main support surface being the outer cylindrical surface – this biases against the inside cylindrical surface of the outer bearing. If the two cylindrical surfaces cease to be coaxial the rotation of the shaft and inner bearing drives the fluid (oil) circumferentially around the radial gap into the thinnest region of the gap, thus forcing the bearing surfaces back into coaxial arrangement. Axial load bearings are generally also cylindrical however the main support surface is the circular or ring-shaped face of the inner cylinder, biasing against complementary bearing surfaces on one or both sides of the cylinder.

Preferably the drive means and each armour plate is arranged such that the or each armour plate can be spun, about an axis, and the thickness of the armour plate is such that at substantially across

the surface of the armour plate the thickness of any part of the armour plate in millimetres, multiplied by the speed in meters per second of that part of the armour plate when driven to spin by the drive means, multiplied by the density of that part of the armour plate in grams / mm³, is greater than 5000 mm . m/s . g/mm³, more preferably greater than 10,000 mm . m/s . g/mm³, more preferably greater than 20,000 mm . m/s . g/mm³.

Preferably the disk has a thickness that varies with position from an axis of rotation, and across a majority of the area of the disk, for any given position the thickness of the disk at that position (multiplied by the average density at that position) is substantially inversely proportional to the radius of that position from the axis of rotation. The axis of rotation may be the respective axis of the disk. This is advantageous because across most of the disk the thickness is optimal for a given rotation speed so that all of these parts of the disk provide material (more accurately, mass) at substantially the same rate, while avoiding unnecessary mass near the periphery of the disk which maximises the speed that the disk can be spun at without it disintegrating from centripetal forces.

Optionally the disk is of aluminium alloy. (E.g. Aluminium alloyed with any combination of copper, magnesium, manganese, silicon, tin and zinc, preferably including zinc to maximise tensile strength) This has excellent strength to weight ratio under tension, which enables high speed rotation without disintegration from centripetal forces.

Optionally the disk has variations in thickness or variations in the average density across its thickness, the variations being exhibited in the circumferential direction, such that as it rotates it presents a varying rate of mass at a (or indeed substantially any) particular position.

This may be provided by means of radially extending ribs, but to minimise air friction (if relevant) it may be provided by radial hollow tubes, or integrally cast radial bars of a metal of different density (such as radial steel bars cast inside aluminium alloy). This has the advantage that as a shaped charge jet cuts into the disk, and the disk rotates while being cut by the jet, the jet is subjected at a varying rate to incident mass, such that different parts of the jet will be diverted by differing amounts. As a result the jet will not be travelling in a consistent straight line when impacting into the base armour, which enables the base armour to absorb it much more easily.

Preferably the drive means and each armour plate is arranged such that the or each armour plate can be spun such that the speed of the periphery of the respective plate in m/s multiplied by its thickness at that location in mm, is at least 1000.

Preferably the drive means and each armour plate is arranged such that the or each armour plate can be spun such that it performs a full rotation at least 200 times per second.

Preferably the plate is a steel disk.

In embodiments where the armour plates are disks, the respective axis is generally the axis of the disk. Furthermore, in embodiments where the thickness of the disk tapers radially, the taper may be linear or may be hyperbolic. The taper may begin at the axis of the disk (maximum thickness at the axis, decreasing towards the circumference) or at a radius from the axis of the disk (maximum thickness at a radius from the axis, decreasing towards the circumference).

A reference to the periphery of an armour plate may refer to a position on the circumference of an armour disk. Alternatively the periphery may be a position on the outer edge of an armour plate of a different geometry, for instance a position on the outer edge of a square plate.

A benefit of the invention is that the armour panel is less sensitive to angle of attack when compared to conventional explosive reactive armour (ERA). However, optionally the armour plates may comprise explosive reactive armour. In particular explosive reactive armour may be used at the, or in proximity to, the respective axis of the armour plate and extend radially towards the periphery of the armour plate a predetermined distance. The tangential speed of a position on the surface of a rotating armour plate will decrease as the radius of rotation (distance from the armour plate respective axis) decreases. Therefore close to the respective axis of the armour plate, less material is presented to the shaped charge jet for each rotation of the armour plate. A substantial increase in thickness is therefore required relative to other parts of the armour plate that are larger distances from the respective axis. The use of explosive reactive armour at positions at the, or in proximity to the respective axis of the armour plate, would therefore prevent the armour plate from needing to be undesirably thick.

The armour plates may spin at an angular velocity that is proportional to their thickness. For instance a thicker armour plate may not require as high an angular velocity as a less thick plate. In some embodiments, the active armour layer may be configured to spin the armour plates before impact of a shaped charge jet, or alternatively upon impact. Other embodiments may spin the armour plates at a low speed before detection of a shaped charge jet, then accelerate the armour plates to a higher speed upon detection of a shaped charge jet.

In some embodiments of the invention the armour panel further comprises at least one warning sensor, the at least one warning sensor being configured to detect the shaped charge jet and upon detection to trigger the drive means to spin at least one of the armour plates. The spinning of the armour plates may be initiated by a person inside a vehicle which the armour plates are protecting (for instance when the person feels threatened or identifies an inbound shaped charge jet or other weapon). Alternatively, the armour plates may start spinning when a warning sensor, for instance a passive sensor (such as a sensor detecting visible or infrared emissions) detects the launch of, or indeed the inbound, shaped charged jet. Alternatively an active sensor (such as a radio frequency emitting and receiving antenna) may detect a moving object inbound towards the armour layer, then initiating the spinning of the armour plates. Either type of sensor may be connected directly to, or via computer or other control means, to the drive means of the active armour layer, thereby allowing the armour plates to be spun when the sensor detects the shaped charge jet. In embodiments where each armour plate has a respective drive means, each armour plate may comprise a respective warning sensor that can trigger only the respective armour plate to spin, or alternatively a single warning sensor may be used to trigger the rotation of all of the armour plates, or a subset of the armour plates. The warning sensor itself is preferably capable of detecting the

shaped charge jet at sufficient range to provide approximately 0.1s of warning time before impact. However even more preferably, the warning sensor is capable of detecting the shaped charge jet at sufficient range to provide approximately 1s of warning time before impact. The warning sensors may be cooled (for instance cryogenically) in order to improve their sensitivity.

- 5 The armour plates may alternatively only start spinning upon impact by a shaped charge jet. Such a configuration would require the shaped charge jet to undergo substantial acceleration in very short timescales (so as to achieve the rotational speeds proportionate to the speed of a shaped charge jet quickly).

- 10 To achieve very high accelerations, embodiments of the invention may use explosive force to spin the armour plates. For instance, two armour plates may be explosively driven in opposite directions through use of explosive charges connecting the plates. Alternatively each armour plate may include a plurality of explosive charges or pyrotechnics, fired together or at predetermined intervals to provide the required acceleration.

- 15 Embodiments of the invention may comprise armour plates made from high fracture toughness and high specific strength materials.

Optionally the armour elements are armour cylinders, and for each armour cylinder the respective axis being concentric to the armour cylinder, the armour cylinders being arranged in a substantially adjacent fashion and such that for each armour cylinder, the respective axis is substantially parallel to the plane of the base armour layer.

- 20 Maximum tangential speed for a rotating disk is realised at the circumference of the disk. A rotating armour cylinder will present a surface to an incoming shaped charge jet where any location on that surface is on the circumference of a rotating disk (for instance a cross section of the cylinder at any point along its length will be a disk with a radius that is the radius of the cylinder). Therefore any location will experience the maximum tangential speed for a rotating disk of that diameter. As such
- 25 a shaped charge jet incident upon a rotating cylinder arranged with its concentric axis parallel to an underlying base armour layer, will be presented with material travelling at maximal tangential speed. Furthermore the shaped charge jet will be presented with an active armour layer of thickness equal to the cross sectional diameter of the armour cylinder. The combination of thickness and speed of rotating material ensures mass is presented to the shaped charge jet at a high rate. In some
- 30 embodiments the armour cylinders may be hollow, partially filled, or completely solid armour cylinders.

According to a second aspect of the present invention there is provided a method of protecting a target from shaped charge jets, comprising the steps of:

- 35 Providing a base armour layer, for resisting military bullets, missiles and/or shells directed from an outboard direction; and

Providing an active armour layer for disrupting a shaped charge jet, the active armour layer being disposed outboard of the base armour layer;

Wherein:

The active armour layer comprises an array of armour elements, arranged in a substantially adjacent or overlapping fashion; and

The method comprises the step of spinning by means of a drive means, at least any one of the armour elements about a respective axis such as to disrupt any incoming shaped charge jet of a shaped charge jet warhead or of a rocket propelled grenade.

In preferred embodiments of the method, the armour elements are armour plates and the respective axis is substantially perpendicular to the plane of the base armour layer. In other embodiments of the method the armour elements are armour cylinders and for each armour cylinder the respective axis is concentric to the armour cylinder, the armour cylinders being arranged such that for each armour cylinder, the respective axis is substantially parallel to the plane of the base armour layer.

A preferred embodiment of the invention will now be described by way of example only, in which:

Figure 1 illustrates in cross section a known type of explosive armour panel;

Figure 2 illustrates in cross section a known type of explosive armour before and during impact by a shaped charge jet;

Figure 3 illustrates a front view of an armour plate according to one embodiment of the present invention;

Figure 4 illustrates a side view of an armour plate of one embodiment of the present invention;

Figure 5 illustrates a side view of an armour plate of another embodiment of the present invention;

Figure 6 illustrates a perspective view of part of a disk, showing a row of radial hollow tubes;

Figure 7 illustrates overlapping plate armour according to one embodiment of the present invention; and

Figure 8 illustrates an armoured vehicle mounted with an armour panel of one embodiment of the present invention.

Figure 9 illustrates an embodiment of an armour cylinder.

Figure 10 illustrates an armoured vehicle mounted with an armour panel comprising armour cylinders;

Figure 11 illustrates a front view of an armour plate according to an embodiment of the invention comprising a warning sensor;

Figure 12 illustrates a side view of an armour plate according to any embodiment of the invention comprising a warning sensor.

Turning to figure 1 a known explosive reactive armour panel 1 is shown. The base 2 is steel and the upper 3 (shown in enlarged view above) is of a metal explosive metal sandwich. Figure 2 shows the sandwich 3 before (top) and during (bottom) impact by a shaped charge jet 4. The jet causes the explosive 5 to explode which throws the metal foil or plate 6 into the path of the jet 4, thereby causing some disruption to the main part of the jet. As the jet ceases to be straight it will not all impact on the same tiny area of the base armour 2, and thus will be absorbed in the base rather than penetrate it.

Turning to figure 3, a plate 7 is shown which forms part of the plate armour of one embodiment of the present invention. The plate is generally a disk i.e. circular and thin.

Figure 4 shows a plate of one embodiment in cross section. A shaft 8 is provided to hold the disk 7 in place, but explosives (not shown) are arranged opposed to baffles 9 to instantaneously accelerate the disk to rotate at its top speed. This embodiment will only operate once, and requires activation in advance of an incoming threat, for example based on a radar or optical warner as can be found on some military vehicles (not shown).

Figure 5 shows a plate of a different embodiment in cross section. A motor 10 is provided with gearing to two shafts 8, 8', to drive two disks 7, 7' in opposite directions. These disks rotate continuously so that unexpected attacks can be resisted. The use of two disks with opposed rotation directions provides for balancing the torque that they generate when the vehicle turns or rotates over uneven terrain, however single disks rotating in opposite directions could also provide for balancing the torque from the disks especially if they share a common housing or other rigid mounting.

Figure 6 shows a perspective view of a segment of one disk 7 according to an embodiment of the invention. The disk has radial holes 11 cast within it such that as it rotates it provides a rapidly varying rate of mass to interfere with the jet, thus causing different parts of the jet to be deflected to differing amounts.

Figure 7 shows an array of six disks 7 according to an embodiment of the present invention. These disks overlap to present a panel of plate armour, in combination with a base layer of armour (not shown). Although there are some gaps as seen from a direction along the axis of one of the plates, this may be acceptable, especially if the expected angle of attack is oblique, which is often the case.

Figure 8 shows an armoured vehicle 12, in this case a tank, clad with two panels of armour according to an embodiment of the invention, each comprising multiple plates 7. By arranging the disks in a plate armour fashion around the most vulnerable areas of the vehicle, the threat of shaped charge jet weapons can be fully or partially mitigated. Each disk is housed independently in its own housing (not shown), such that if it disintegrates due to being damaged, the shrapnel will not cause neighbouring disks to be damaged. The housings typically are of cast iron, with the casting arranged to provide separate voids for each disk. Especially in the case that the disks are arranged to spin continuously, the housings preferably are partially evacuated to reduce air friction losses.

In one example an incident shaped charge jet of Aluminium is circular in cross section and has a tip speed of 10-14km/s, while the main part of the jet has a speed of around 6.5km/s. The thickness of the main part of the jet is 1mm.

The base armour layer (e.g. 30cm thick rolled steel armour) would be entirely penetrated by the whole jet if undisturbed, but if the main part of the jet is disturbed so that it does not travel in a straight line following the tip, the base armour is able to absorb and stop the shaped charge jet.

The plate is an Aluminium alloy disk with a thickness that varies inversely proportional to radius (barring an axially central portion which has a single consistent thickness and may have a drive shaft extending from it). The disk has a radius of 0.5m and at its periphery, has a thickness of 1mm.

In order to completely disperse the 1mm thick jet, a 1mm wide section of the disk should be moved into its path at roughly the same speed (6.5km/s), however it is extremely difficult to achieve such speeds in a rotating disk (this would require 500,000rpm which would clearly cause the disk to disintegrate).

By selecting a disk with a peripheral thickness of 10mm, the jet can be essentially fully dispersed with a disk speed of only around 50,000rpm, although this is still excessively challenging.

By accepting that the jet will not be fully dispersed, and only injecting mass at a rate of about $1/5^{\text{th}}$ that of the main jet, a lower disc speed of 10,000rpm can be used.

However even by moderately dispersing the jet, this greatly reduces its ability to penetrate the base armour, especially if the disk has circumferential variations in density and/or thickness such as to provide varying disruption to the jet.

Methods of rotating disks of such sizes can be implemented by the person skilled in the art. For example by utilising a motor of a large angle grinder, a disk of the type described with a radius of 0.5m can be spun at 10,000rpm, albeit requiring stronger and more heavy duty bearings than are typical (e.g. fluid dynamic bearings of the type used in turbochargers for large vehicles), especially if mounted on a moving vehicle.

Importantly, if a second jet is fired in the same direction a short period of time later, the remainder of the disk will still be present to interfere with that jet too. For example if a 0.5m radius disk is spun at 10,000rpm then a double-headed warhead would have to spread out its attack over $1/166^{\text{th}}$ of a second (e.g. waiting around $1/200^{\text{th}}$ of a second before firing the second shaped charge jet) in order for the wheel to complete one rotation. Due to the approach speed of a typical warhead this would not be possible. Therefore, in such scenarios the disk is able to disrupt both jets of a double-headed warhead.

The person skilled in the art will be able, by simple trial and error, to select a base armour layer thickness (and material – typically steel) to suit a particular shaped charge jet weapon of interest.

In the case of a copper jet rather than an aluminium jet, the density of the jet is about 3 times higher, and consequently the rate at which the disk presents material must also be greater. A speed of at least 30,000 rpm would be recommended.

Conversely, by using a disk of steel rather than aluminium, this brings the density of the disk near to the density of the copper jet, and so these higher disk speeds can be avoided.

That said, as the head of the jet is likely to punch a hole in the disk of larger diameter than the head of the jet and certainly larger diameter than the main part of the jet, the disk needs to spin fast enough that the edge of that hole reaches and begins disrupting the main part of the jet, before most of the main jet has passed through the hole. For this reason speeds in excess of 30,000rpm are preferred, even where a steel disk is used. Further embodiments are set out in the claims.

Figure 9 shows an armour cylinder 14 in accordance with an aspect of the invention. The armour cylinder being configured to spin about concentric axis A. Figure 10 shows an armoured vehicle 12 clad with armour cylinders 14. The armour cylinders when in use rotate about their respective concentric axis, thereby presenting a high rate of mass to a shaped charge jet.

Figure 11 shows an armour plate 15 of an embodiment of the invention. The armour plate 15 further comprises a warning sensor 16 at the respective axis of the armour plate 15. Figure 12 shows the armour plate 15 of Figure 11 but in cross sectional view. The angular field of view 17 of warning sensor 16 is shown by the dotted lines in the figure. The warning sensor 16 may be a passive sensor such as an infrared sensor. When a shaped charge jet 18 within the field of view 17 of the warning sensor 16 is detected, the warning sensor 16 triggers the drive means to spin the armour plate 15. The warning sensor 16 may be rotationally detached from the armour plate 15, or may rotate with the respective armour plate 15 and be interfaced with electrically via slip rings.

Claims:

1. An armour panel comprising:

A base armour layer arranged substantially in a plane, for resisting military bullets, missiles and/or shells directed from an outboard direction; and

An active armour layer for disrupting a shaped charge jet of a shaped charge jet warhead or of a rocket propelled grenade, the active armour layer being disposed outboard of the base armour layer;

Wherein the active armour layer comprises:

An array of armour elements, arranged in a substantially adjacent or overlapping fashion; and

Drive means for spinning at least any one of the armour elements about a respective axis for disrupting the shaped charge jet.

2. The armour panel of claim 1 wherein the armour elements are armour plates and the respective axis is substantially perpendicular to the plane of the base armour layer.

3. The armour panel of claim 2 wherein the armour plates are disks.

4. The armour panel of claim 3, wherein each disk has an axial thickness that tapers from a maximum axial thickness substantially at the axis of the disk, to a minimum axial thickness substantially around the circumference of the disk.

5. The armour panel of any one of claims 2-4, wherein the armour panel comprises a drive shaft connected to each armour plate and further comprises for each armour plate, drive means interfacing with the drive shaft, to maintain the armour plates spinning for disrupting such a shaped charge jet.

6. The armour panel of any one of claims 2-5, wherein the armour panel comprises means respectively coupled to each of the armour plates to provide substantially instantaneous acceleration of the armour plates, for disrupting such a shaped charge jet.

7. The armour panel of any one of claims 2-6, wherein the armour plates are preferably arranged in respective housings, each housing being arranged to contain shrapnel arising from the disintegration of the armour plate, to prevent damage to neighbouring armour plates.

8. The armour panel of any one of claims 2-7, wherein each armour plate is provided with respective drive means.

9. The armour panel of any one of claims 2-8, wherein the plates are arranged on fluid dynamic bearings.

10. The armour panel of any one of claims 2-9, wherein the drive means and each plate is arranged such that the or each plate can be spun about an axis, and the thickness of the armour plate is such that at substantially across the surface of the armour plate the thickness of any part of the armour plate in millimetres, multiplied by the speed in meters per second of that part of the armour plate when driven to spin by the drive means, multiplied by the density of that part of the armour plate in grams / mm³, is greater than 5000 mm . m/s . g/mm³.

11. The armour panel of any one of claims 2-10, wherein the armour plates are disks, and each disk has a thickness that varies with position from an axis of rotation, and across a majority of the area of the disk the thickness of the disk at that position, multiplied by the average density at that position, is substantially inversely proportional to the radius of that position from the axis of rotation.

12. The armour panel of any one of claims 2-11, wherein the armour plates are disks and each disk is of aluminium alloy.

13. The armour panel of any one of claims 2-12, wherein the armour plates are disks and each disk has variations in thickness, or variations in the average density across its thickness, the variations being exhibited in the circumferential direction, such that as it rotates it presents a varying rate of mass at a (or indeed substantially any) particular position.

14. The armour panel of any one of claims 2-13, wherein the drive means and each armour plate is arranged such that the or each armour plate is arranged to be spun such that the speed of the periphery of the respective armour plate in m/s multiplied by its thickness at that location in mm, is at least 1000.

15. The armour panel of any one of claims 2-14, wherein the drive means and each armour plate is arranged such that the or each armour plate can be spun such that it performs a full rotation at least 200 times per second.

16. The armour panel of any one of claims 2-15, wherein each armour plate further comprises explosive reactive armour at the, or in proximity to, the respective axis.

17. The armour panel of any one of claims 2-16 further comprising at least one warning sensor, the at least one warning sensor being configured to detect the shaped charge jet and upon detection to trigger the drive means to spin at least one of the armour plates.

18. An armour panel according to claim 1 wherein the armour elements are armour cylinders and for each armour cylinder the respective axis is concentric to the armour cylinder, the armour cylinders being arranged such that for each armour cylinder, the respective axis is substantially parallel to the plane of the base armour layer.

19. A method of protecting a target from shaped charge jets, comprising the steps of:

Providing a base armour layer in substantially a plane, for resisting military bullets, missiles and/or shells directed from an outboard direction; and

Providing an active armour layer for disrupting a shaped charge jet of a shaped charge jet warhead or of a rocket propelled grenade, the active armour layer being disposed outboard of the base armour layer;

Wherein:

The active armour layer comprises an array of armour elements, arranged in a substantially adjacent or overlapping fashion; and

The method comprising the step of spinning by means of a drive means, at least any one of the armour elements about a respective axis such as to disrupt any incoming shaped charge jet of a shaped charge jet warhead or of a rocket propelled grenade.

20. The method of claim 19 wherein the armour elements are armour plates and the respective axis is substantially perpendicular to the plane of the base armour layer.

21. The method of claim 19 wherein the armour elements are armour cylinders and for each armour cylinder the respective axis is concentric to the armour cylinder, the armour cylinders being arranged such that for each armour cylinder, the respective axis is substantially parallel to the plane of the base armour layer.

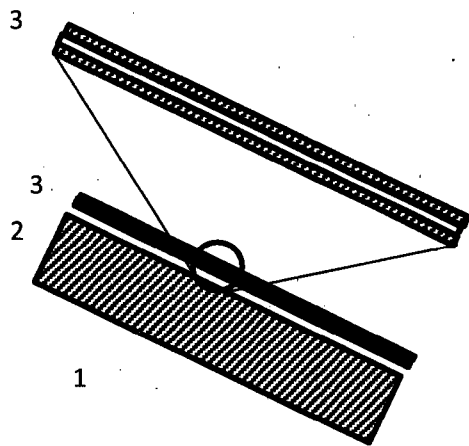


Figure 1

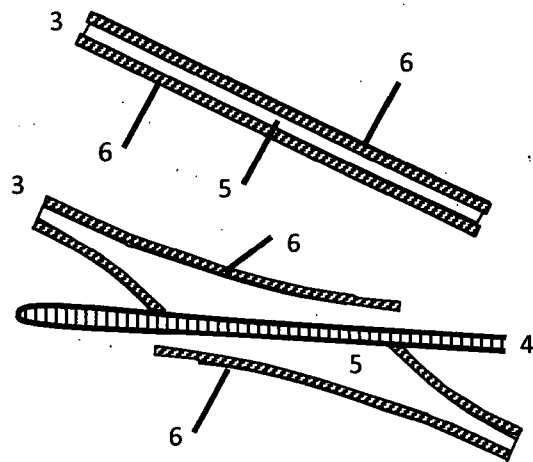


Figure 2

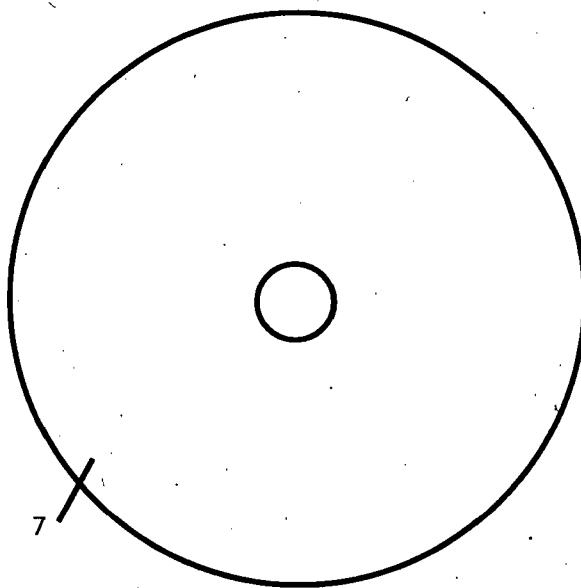


Figure 3

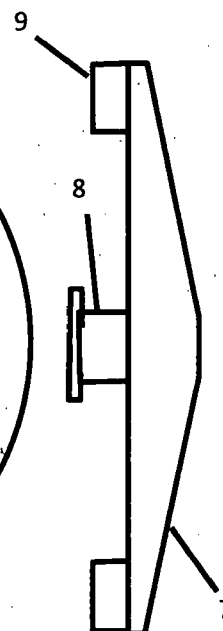


Figure 4

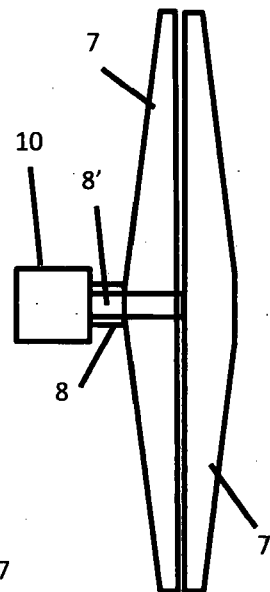


Figure 5

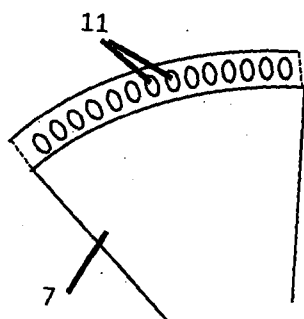


Figure 6

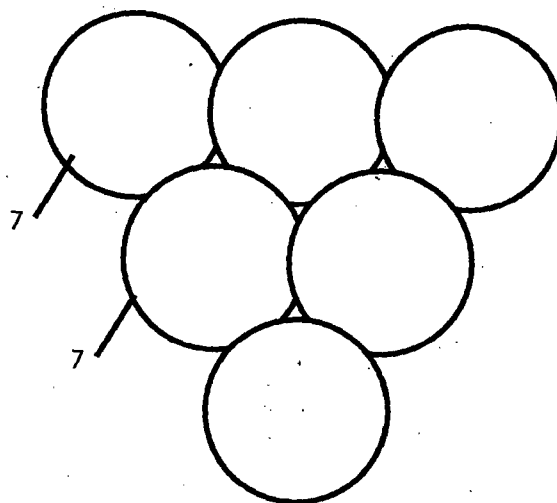


Figure 7

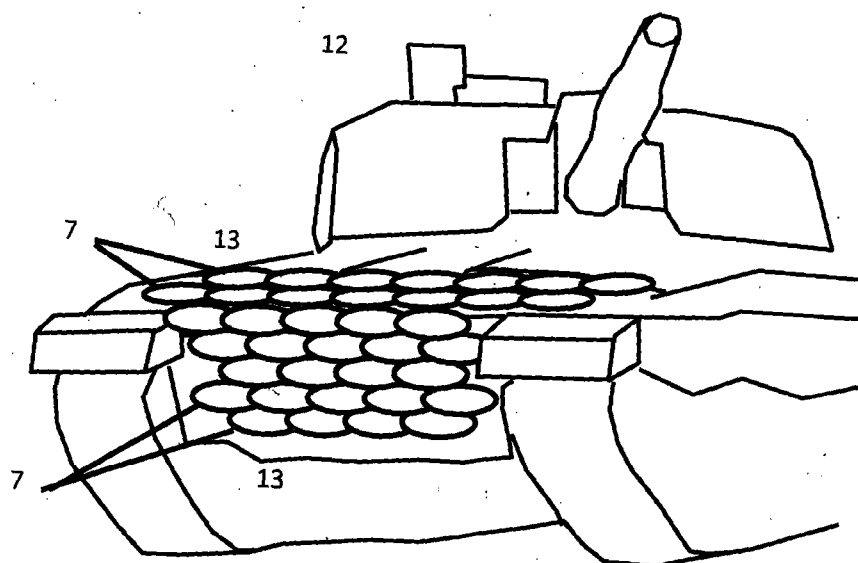


Figure 8

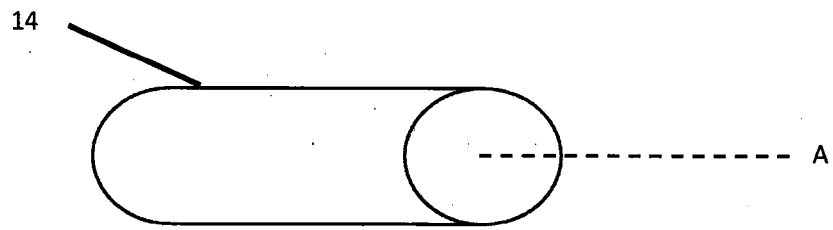


Figure 9

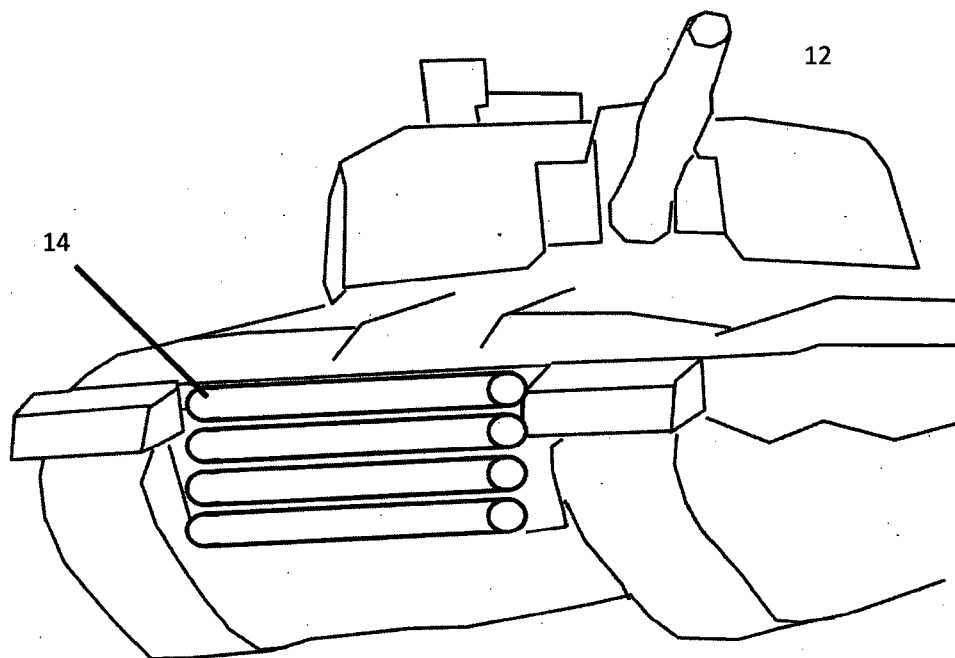


Figure 10

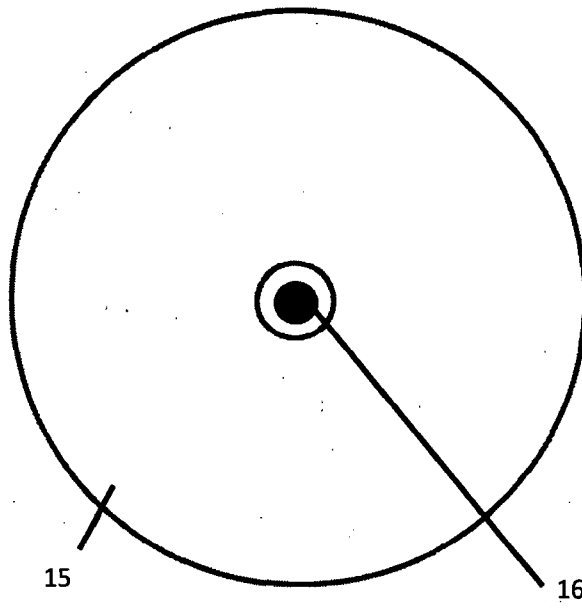


Figure 11

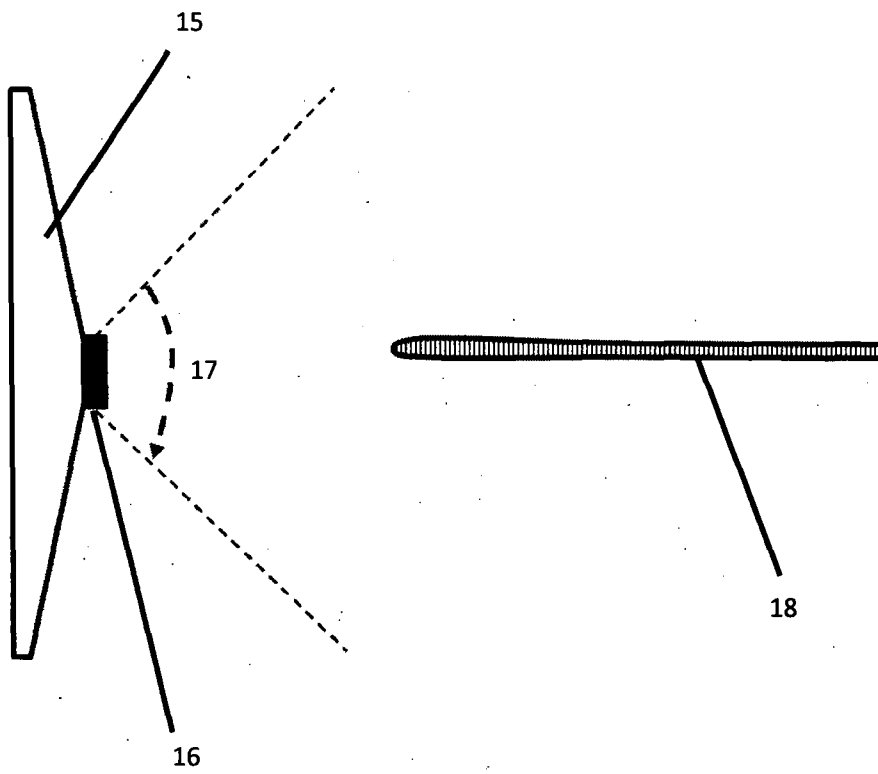


Figure 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/000140

A. CLASSIFICATION OF SUBJECT MATTER
INV. F41H5/007
ADD.

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)
F41H

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 866 839 A (OHAYON SHALOM [US]) 2 February 1999 (1999-02-02) column 5, line 40 - line 45; claim 1; figures 1-16 -----	1
A	US 5 402 704 A (DONOVAN WILLIAM F [US]) 4 April 1995 (1995-04-04) claim 1; figures 1-18 -----	1
A	WO 2014/035365 A1 (JH QUANTUM TECHNOLOGY INC [US]; HUNT JACK [US]) 6 March 2014 (2014-03-06) paragraph [0059]; figure 6 -----	1



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

9 November 2017

Date of mailing of the international search report

20/11/2017

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Authorized officer

Beaufumé, Cédric

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2017/000140

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5866839	A	02-02-1999	NONE

US 5402704	A	04-04-1995	NONE

WO 2014035365	A1	06-03-2014	CA 2922635 A1 06-03-2014
			EP 2926361 A1 07-10-2015
			WO 2014035365 A1 06-03-2014
