

ARMOUR MODULE FOR VEHICLE

Field of the invention

The present invention is related to a lightweight armour module, in particular, a stand-off armour module for a vehicle or similar object. The invention further relates to an arrangement of such modules and a vehicle comprising such armour.

Background of the invention

Rocket Propelled Grenades are one form of weapon used by armies and also by terrorist groups to target military objects. In some countries they can be acquired relatively easily and yet are highly effective against even the most heavily armoured targets. An RPG is generally shoulder fired from a launcher and flying at a maximum speed of around 300 m/s can hit a target at up to 1000m. On impact, a contact fuse on the nose of the grenade causes an explosive charge to extrude a rapier like jet of copper through the nose cone. Depending upon the type of warhead, this is capable of piercing in excess of 350 mm of steel plating and causing significant devastation thereafter - a phenomenon known as Behind Armour Effect. A vehicle protected using steel plate alone, would therefore be extremely heavy, bulky and difficult to move. In order to reduce the dependence on plate armour, additional armour concepts have been combined, capable of defeating different forms of weapon.

Armour systems designed for the defeat of RPGs often take the form of bar-shaped armour structures arranged at a certain distance or stand-off from the target or vehicle. The stand-off distance is usually greater than 30 cm. This bar-armour usually consists of a rigid array of steel or aluminium bars arranged in a relatively horizontal direction with vertical stabilizing elements. The spacing between the bars is such that an RPG will not be able to pass through and directly strike the body of the vehicle. Effective detonation of the explosive charge is thus avoided.. Even if the RPG does pass through the bar armour and the trigger is activated on impact, the deformation of the nose cone by the bar-armour should be sufficient to prevent effective initiation of the armour penetrating rapier. In combination with such bar-armour a relatively thinner form of plate armour may suffice.

Conventional bar armour used on vehicles is relatively heavy and robust in order to resist impact and general wear and tear during operation of the vehicle. It is generally

rigidly mounted to the vehicle by welding or bolting and must often be made to measure in order to completely surround and protect the vehicle. Equipping a vehicle with bar armour is a costly exercise and once applied, removal or repair is difficult. A vehicle provided with bar armour becomes around 80 cm wider and may not be able to travel on normal roads or be transported e.g. in an aircraft or train without removal of the armour and supports. For instance, one of the current protected troop carrier vehicles in service with the UK Ministry of Defence is too wide to be legally driven on UK roads due to the fixed bar armour. Access to the vehicle and its running gear for maintenance may also be restricted. This is especially problematic for tracked vehicles.

Due to its bulky nature and the additional vehicle width, the bar armour is also often the first part of a vehicle to contact an obstacle and for this reason is frequently damaged. The robust nature of the fixed brackets for supporting bar-armour renders each bar-shaped armour module highly bulky and presents a logistical challenge for the transport of new or replacement panels which weigh little but take up a high volume of space.

Normally the space requirement within a transport aircraft or vehicle is of greater concern to military operations than the weight.

Adaptations of conventional bar-armour have been suggested. US patent 7882776 discloses armour for a vehicle comprising a grid of horizontal carbon fibre bars arranged in slots formed in vertical metallic bars. The structure is relatively lighter than a corresponding metal structure but nevertheless may be prone to damage and distortion due to the rigid nature of the grid.

EP2265889 A1 discloses a vehicle and structure shield comprising a flexible net system carried by a frame with mounting brackets for positioning the frame at a stand-off from the vehicle. A releasable fastener system such as hook and loop fasteners may be used for securing the net system to the frame and for securing the mounting brackets of the frame to the vehicle. Although such systems are believed to be promising, they are not as robust and may not always provide comparable protection to bar-armour. The high strength polymer fabric material used for the net is also very expensive and can suffer from environmental degradation.

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Summary of the invention

The current invention aims to provide a lightweight armour module capable of overcoming at least some of the above-mentioned drawbacks.

According to the present invention, an armour module for a vehicle is provided. The armour module comprises a plurality of flexible vertical elements to be arranged substantially parallel to each other in a substantially vertical direction; a plurality of horizontal slats to be arranged substantially parallel to each other in a substantially horizontal direction; and a connection arrangement for supporting the armour module in a stand-off relation to the vehicle.

The use of flexible vertical elements in combination with horizontal slats provides a flexible, lightweight armour module that may be easy-to-store, easy-to-use and easy-to-replace. In the present context, reference to a vehicle is intended to denote that the armour is suitable for being mounted to a vehicle such as a road vehicle, off-road vehicle, tank, boat, or even an aircraft such as a helicopter. Nevertheless, it will be understood that the same principle may be applied to fixed or semi-mobile structures such as armoured placements, observation platforms or the like. Furthermore, although reference is given to vertical and horizontal elements, it will be understood that such orientation is relative and not otherwise essential and that the armour module may be mounted at any angle with respect to the object which it protects.

In a preferred embodiment, the slats are also flexible, at least in a direction perpendicular to a plane of the slat. Preferably they have a flexural modulus of between 10 GPa and 200 GPa. The degree of flexibility may be adapted such that adjacent slats will not spread apart on impact to allow an RPG to pass through. The resulting module is thus flexible in multiple directions and may also be twisted without damage. The slats are preferably made of composite material, in particular, glass or carbon-fibre reinforced materials including, but not limited to polyester, vinylester, PPS, PET and epoxy resins. By use of lightweight materials an areal density of the armour module of less than 25 kg/m^2 may be achieved. The degree of flexibility may also determine the spacing of the vertical elements. A highly rigid carbon fibre slat having a flexural modulus close to 200GPa may require relatively few vertical elements. Glass fibre slats are more compliant, and may have a flexural modulus of around 20GPa. In that case a closer spacing of the vertical elements may be desirable.

Within the context of the present invention, the term "slat" is intended to denote a relatively elongate element having a width and a relatively low profile or height, at least at a leading edge i.e. the side of the slat directed away from the vehicle and facing towards an oncoming projectile. In general such slats may be rectangular in cross-

section although other shapes may be considered including triangular or curved shapes. Preferably, the slats have a width of between 4 cm and 10 cm, preferably around 5 cm. The height of the profile at the leading edge is preferably less than 10 mm. In general the slats will be straight although it will be understood that they may also be provided
5 with complex shapes e.g. to match the body to which they are applied. In particular, for protecting a corner of an object, a hockey-stick shaped slat may be provided.

As discussed above, the spacing between adjacent slats should be sufficient to prevent an RPG from passing through. In general, a spacing of from 3 cm to 8 cm is desirable, preferably between 4 cm and 6 cm and most preferably around 5 cm.

- 10 According to a further aspect of the invention, the vertical elements may extend through openings in the horizontal slats. Such a structure is relatively simple to manufacture. The vertical elements may be aligned with one another but may also be offset to different positions within the width of the slats. In this manner, the stability of the module may be adapted according to the degree of offset. It will be understood that
15 as the offset of the vertical elements is increased, the ability to roll up the module is reduced.

- In a further preferred embodiment, a plurality of fastening elements may fasten the horizontal slats and vertical elements together. These may comprise crimps, clips, swages or the like applied to the vertical elements which serve to engage the horizontal
20 slats. The fastening elements may comprise flexible provisions that allow the horizontal slats limited movement with respect to the vertical elements. This relative movement may be vertical, horizontal, lateral or torsional and may increase the overall flexibility of the structure and assist in allowing the armour module to be rolled, folded or otherwise packed. The flexible provisions may comprise appropriate gaps and may also
25 include resilient washers and packings allowing such relative movement. In an alternative arrangement, the slats may be fastened to each other and the vertical elements may e.g. pass through the horizontal slats without use of fastening elements. Such an arrangement allows the slats to be retracted in the manner of a domestic venetian blind, whereby adjacent slats may stack together. Automatic retraction may
30 also be provided. Other provisions for varying the distance between adjacent slats may be included. The skilled person will be aware of various structures which may be used to form the vertical elements including glass, carbon and other high-strength fibres, metal cable, belts, chains, links and other segmented elements. According to one

preferred embodiment, the vertical elements comprise steel cable of an appropriate gauge. For most purposes, cable gauges of from 4 mm to 12 mm may be sufficient, preferably around 6 mm.

In general, the slats may be arranged to lie flat i.e. in a horizontal plane. Nevertheless, 5 the slats may also be tilted upwards or downwards in the manner of venetian blinds. This may further assist in deflecting or distorting an incoming RPG.

According to an important embodiment of the invention, the slats comprise interconnections at their ends for connection to the slats of an adjacent armour module. The interconnections may take various forms and may be provided by ancillary clips or 10 connectors. In a simple embodiment, the slats may be provided with further openings near their ends through which a cable or the like may be threaded to retain both sets of slats together.

The invention also provides for a vehicle provided with one or more armour modules as described above. Each armour module may be connected to an adjacent armour module 15 by interconnections between ends of the slats.

According to another aspect of the present invention, stand-off armour for a vehicle is provided comprising a flexible protecting element and one or more supports for securing the protecting element to the vehicle, wherein the supports are resilient and capable of being deformed in response to deformation of the protecting element and 20 thereafter returning to a stand-off position. Such an arrangement reduces damage to the vehicle or supports due to impact on the protecting element and furthermore allows the flexible protecting element to more adequately function. It will be understood that the resiliency of the supports is such that they may deform e.g. in response to collision with an object during driving of the vehicle. It is not intended that they should significantly 25 deform in response to impact by an RPG on the protecting element. The protecting element may be as defined above although the skilled person will be aware that the use of resilient supports is not limited to slat based structures.

In a preferred embodiment the supports comprise upper brackets from which an upper side of the protecting element is suspended. The upper brackets support the weight of 30 the protecting element and may provide the primary point of retention on the vehicle. The upper brackets may themselves be resilient or may comprise rigid members connected together by flexible means such as resilient suspension blocks.

Preferably, the supports further comprise one or more tensioning elements, arranged to apply a tension to a lower side of the protecting element. The tensioning elements may comprise struts which may be biased in a bending mode to tension the protecting element and maintain the stand-off between the vehicle and the protecting element. The struts may be formed of steel, aluminium, polymer or composite materials, preferably of fibre reinforced composites.

In addition to being resilient, the supports may also be stowable, allowing the armour module to be retracted against the vehicle body for transportation purposes or to pass through a narrow space. The supports may also be arranged to retract or fold flat against the vehicle structure when the armour module has been removed.

Brief description of the drawings

The features and advantages of the invention will be appreciated upon reference to the following drawings of an exemplary embodiment, in which:

Figure 1 is a perspective view of an armour module according to an embodiment of the present invention;

Figure 2 is a close up view of part of the armour module of Fig. 1 taken on line II-II;

Figure 3 is a perspective view of stand-off armour according to an embodiment of the present invention;

Figure 4 is a side view of the stand-off armour of Fig 3;

Figure 5 is a perspective view of a vehicle with a plurality of stand-off armour modules.

Figure 6A and 6B are side views of an upper bracket according to an alternative embodiment of the invention.

Detailed description of embodiments

In Fig.1 a perspective view is shown of an armour module 1 according to an embodiment of the current invention. The armour module 1 comprises flexible vertical elements 3 arranged generally parallel to each other and denoted 3A, 3B and 3C.

Horizontal slats 5, arranged substantially parallel to each other in a horizontal direction are supported from the vertical elements as described in further detail below. A

connection arrangement 7 is provided for supporting the armour module 1 in a stand-off relation to a vehicle.

The connection arrangement 7 comprises a top frame 31, a bottom frame 33 and a plurality of connecting elements 35. The connecting elements 35 are located on both
5 the top frame 31 and the bottom frame 33, preferably at the two end portions of both the top frame 31 and the bottom frame 33.

The vertical elements 3 are flexible steel braided cables having a diameter of around 6 mm. The horizontal slats 5 comprises interconnection openings 11 for connecting to the slats 5 of an adjacent armour module.

10 In the depicted embodiment, the slats 5 are rectangular in cross-section with a width of 5 cm, a length of 100 cm and a height or thickness of around 5 mm. They are formed of carbon fibre reinforced epoxy resin and have a flexural modulus of around 200 GPa. The distance between the adjacent slats 5 is 5 cm. The skilled person will understand that this spacing may be chosen or varied according to the protection required. The areal
15 density of the armour module 1 is around 16 kg/m².

Fig. 2 shows a close-up cross-sectional view of the armour module 1 taken in direction II-II in Fig. 1. As can be seen, openings 9 are provided through the slats 5 which allow the vertical elements 3 to extend there through. The slats 5 are held in place on the vertical elements 3 by fastening elements 13. As can be seen, on either side of each slat
20 5 there is provided a swage 16, crimped onto the vertical element 3A. The swage 16 is an aluminium collar which may be crimped using conventional crimping procedures sufficient to provide a retention force of at least 90% of the cable breaking strength. Between the slat 5 and the swage 16 are located two rubber washers 15, with one attached above the slat 5 and the other attached below. These rubber washers allow the
25 horizontal slats 5 limited movement with respect to the vertical elements 3, in particular allowing twisting movement such that the armour module 1 may be rolled up. Although two rubber washers are shown, it is understood that a single washer or bushing either above or below the slat may suffice.

Fig. 3 is a perspective view of the armour module 1 of Fig. 1 mounted in stand-off
30 arrangement from a vehicle 100. According to Fig. 3, the armour module 1 is carried by a support arrangement 140 which comprises a pair of upper brackets 141 from which the top frame 31 is suspended. The upper brackets 141 are connected to the connecting elements 35 by snap links 142. A pair of tensioning elements 145 is

arranged to apply tension to the bottom frame 33. The upper brackets 141 and tensioning elements 145 are provided with mounting plates 147 by which they can be bolted to a body of the vehicle 100.

According to an important aspect of the invention, the upper brackets 141 comprise
5 resilient suspension blocks 143. These blocks 143 are rubber pads that allow the brackets 141 to distort and return to their original position without exerting excessive force on the mounting plates 147 or causing permanent distortion. Although rubber pads are shown, other resilient connections may be used including springs and hinged arrangements. The tensioning elements 145 are formed as struts of glass fibre
10 composite and are also resilient. They are pre-biased to a downward position such that once connected to the connecting elements 35 on the bottom frame 33, they exert a downwardly directed force on the armour module 1 and also maintain the stand-off with the vehicle 100.

Connection and disconnection of the armour module 1 from the support arrangement
15 140 is relatively simple. By releasing the snap-links 142, the armour module 1 may be removed and repaired, stored or replaced as required. Once released, the tensioning elements 145 lie flat against the side of the vehicle 100. Disconnection of a lower bar 146 of the upper bracket 141 allows the upper brackets to fold flat against the vehicle 100. The upper brackets 141 may also be completely disconnected at mounting plates
20 147 as required.

Fig. 4 shows a side view of the arrangement of Fig. 3. As can be seen the vertical elements 3 do not all lie in a single plane. Elements 3A and 3C are located closer to a leading edge 6 of the slats 5. This provides greater stability to the armour module 1.

Fig. 5 is a perspective view of a vehicle 100 showing a plurality of stand-off armour
25 modules 1A to 1G according to the present invention. In Fig. 5, the armour modules 1 are of different sizes and shapes corresponding to the shape of the vehicle 100. In order to link each armour module 1 with an adjacent armour module 1, the slats 5 overlap each other slightly such that the interconnection openings 11 align. Interconnection cables 12 are threaded through the interconnection openings 11.

30 In use, an RPG fired at the vehicle 100 and impacting on the armour modules 1A-G will strike one or more slats 5. The nose cone of the RPG will be deformed by the impact to such an extent that even if the trigger is actuated, the RPG will not discharge and will not be effective in penetrating the vehicle body.

Figs 6A and 6B show an alternative upper bracket 241 comprising a mounting plate 247, a four-bar linkage 248 and a connection fork 249 for connection to the connecting elements 35 of the armour module 1. Resilient suspension blocks 243 are provided beneath the mounting plate 247. Additionally, the elements of the four-bar linkage 248 are formed of composite materials allowing flexibility in a lateral direction. A spring (not shown) biases the upper bracket from the extended position shown in Fig. 6B to the stowed position shown in Fig. 6A. The four-bar linkage 248 maintains the connection fork 249 level during this movement allowing the armour module to be raised and stowed against the side of the vehicle once the connecting elements 35 on the bottom frame 33 have been released.

Thus, the invention has been described by reference to certain embodiments discussed above. It will be recognized that these embodiments are susceptible to various modifications and alternative forms well known to those of skill in the art. In particular, the flexible support arrangement may be used with other non-slat based armour modules and the slat armour disclosed may also be connected to alternative support arrangements.

Many modifications in addition to those described above may be made to the structures and techniques described herein without departing from the spirit and scope of the invention. Accordingly, although specific embodiments have been described, these are examples only and are not limiting upon the scope of the invention.

Claims

1. An armour module for a vehicle comprising:
 - a plurality of flexible vertical elements to be arranged substantially
 - 5 parallel to each other in a substantially vertical direction;
 - a plurality of slats to be arranged substantially parallel to each other in a substantially horizontal direction; and
 - a connection arrangement for supporting the armour module in a stand-off relation to the vehicle.
- 10 2. Armour module according to claim 1, wherein the slats are flexible, preferably having a flexural modulus of between 20 GPa and 200 GPa.
- 15 3. Armour module according to any one of the preceding claims, wherein the slats are made of composite, in particular, glass or carbon-fibre reinforced epoxy resin.
- 20 4. Armour module according to any one of the preceding claims, wherein the slats have a width of between 4 cm and 10 cm, preferably around 5 cm.
5. Armour module according to any one of the preceding claims, wherein the vertical elements extend through openings in the slats.
- 25 6. Armour module according to any one of preceding claims, further comprising a plurality of fastening elements that fasten the slats and vertical elements together.
7. Armour module according to claim 6, wherein the fastening elements comprise crimps, clips or swages applied to the vertical elements.
- 30 8. Armour module according to claims 6 or 7, wherein the fastening elements comprise flexible provisions that allow the slats to move with respect to the vertical elements.

9. Armour module according to any one of the preceding claims, wherein the vertical elements comprise metal cables or chains.
10. Armour module according to any one of the preceding claims, wherein the areal density of the armour module is less than 25 kg/m^2 .
11. Armour module according to any one of the preceding claims, wherein the slats may be tilted upwards or downwards relative to the horizontal axis.
12. Armour module according to any one of the preceding claims, wherein the slats are retractable and a distance between adjacent slats is adjustable.
13. Armour module according to any one of the preceding claims, wherein the slats comprise interconnections at their ends for connection to the slats of an adjacent armour module.
14. A vehicle provided with armour modules according any one of the preceding claims.
15. The vehicle according to claim 14, comprising a plurality of armour modules, each armour module being connected to an adjacent armour module by interconnections between ends of the slats.
16. Stand-off armour for a vehicle comprising:
 - a flexible protecting element;
 - one or more supports for securing the protecting element to the vehicle;
 - wherein the supports are resilient and capable of being deformed in response to deformation of the protecting element and thereafter returning to the stand-off position.
17. Stand-off armour according to claim 16, wherein the supports comprise upper brackets from which an upper side of the protecting element is suspended.

18. Stand-off armour according to claim 17, wherein the upper brackets comprise resilient suspension blocks.
- 5 19. Stand-off armour according to any one of claims 16-18, wherein the supports comprise tensioning elements arranged to apply a tension to a lower side of the protecting element.
- 10 20. Stand-off armour according to claim 19, wherein the tensioning elements are struts, biased in a bending mode to tension the protecting element and maintain the stand-off between the vehicle and the protecting element.
21. Stand-off armour according to any of claims 16 to 20, wherein the protecting element is an armour module according to any one of the claims 1 to 13.
- 15 22. Stand-off armour according to any of claims 16 to 20, wherein the protecting element is retractable.
23. A vehicle comprising stand-off armour according any one of claims 16-21.
- 20 24. The vehicle according to claim 22, wherein the stand-off armour is automatically retractable