

SURVIVABILITY ENHANCEMENT

This invention relates to survivability enhancement, and more particularly to systems for enhancing the survivability of armored vehicles and the like.

Armored vehicles and systems are designed to provide ballistic protection commensurate with a specific threat. In connection with such vehicles and systems, the ability to readily vary the armor configuration or to quickly repair damaged armor as a function of particular threats to which the vehicle or system may be exposed may enhance survivability. Further, arrangements which reduce vehicle "signature" (as a function of electromagnetic radiation, infrared radiation, or the like) may also enhance survivability. The appearance of new vehicle armor in the field stimulates the development of new munitions with enhanced capability to defeat the newly fielded armor. Applique armor, that is, supplemental armor applied on top of the basic armor designed into the vehicle or system, has been proposed to enhance survivability. It has been proposed to attach such applique armor to the basic armor by adhesive bonding, by mechanical bolting and by magnetic attachment.

In accordance with one aspect of the invention, there is provided a survivability enhancement system, that includes first fastener structure fixed on the surface of the vehicle or system whose survivability is to be enhanced, and an array of armor tile elements, each armor tile element having opposed surfaces with second fastener structure complementary to the first fastener structure secured to one of its surfaces, one of the fastener structures having a multiplicity of projecting hooking elements (for

example, of the hook or spear type) and the cooperating other fastener structure having complementary structure that is releasably interengaged with the hooking elements, each said  
5 tile element further having perimeter surface portions for mating juxtaposition with perimeter surface portions of adjacent armor tiles to provide a composite supplementary layer of the armor on said vehicle or system. Thus, the armor tiles have an  
10 attachment structure that maintains attachment at effective levels even as the tiles are subjected to large shear forces (for example, upon ballistic impact and shattering of an adjacent tile) and that has effective force dissipation characteristics.  
15 Preferably, the fastener structures in attached relation, have a tension restraint of at least about five psi and a shear restraint of at least about ten psi.

Preferably, the survivability enhancement  
20 system further includes flexible cover structure with fastener structure of the second type secured to the inner surface of the cover structure for fastening interengagement with fastener structure of the first type. The cover structure preferably includes  
25 signature reduction characteristics (in terms of electromagnetic radiation, infrared radiation or the like, as appropriate) and in a particular embodiment is of silicone rubber material with embedded particulate signal reduction material. While the  
30 armor tile may be of various materials, including metals and reactive (e.g., explosive) materials, in particular embodiments, the armor tile material is a ceramic material such as boron carbide, silicon carbide, aluminium oxide or titanium boride.  
35 Preferably, each ceramic armor tile has opposed planar surfaces and is at least about one centimetre

thick and is of polygon configuration with perimeter edge surfaces at least about four centimetres long. Fastener structure of the first type is bonded to one planar surface of the armor tile and separable fastener structure of the second type is bonded to its opposed planar surface.

Preferably, one of the fastener structures includes a series of hook elements that extend upwardly from a base portion, each hook element including a flexible stem portion and a head portion, that projects laterally from one side thereof for engaging a portion of the cooperating fastener structure in fastening relation. While the fastener elements may be of a variety of materials, including metals, in particular embodiments, the base portion and hook elements are of thermoplastic polymeric material such as nylon, polypropylene or the like, and the base portion of the fastener structure is adhesively bonded with epoxy or the like to the surface on which it is secured. In a particular embodiment, the cooperating fastener structure includes a multiplicity of loop elements.

Survivability enhancement systems in accordance with the invention enable easy installation of auxiliary armor elements, as well as easy removal and reapplication to facilitate future armor upgrades. No alterations or modifications of the basic armor of the vehicle or system are required, nor does the survivability enhancement system degrade the structural integrity of the basic armor. Easy replacement of damaged armor tiles in the field is possible. Interactions between adjacent armor tiles and between armor tiles and the base armor are such that destructive impact of a projectile on one tile results in minimal damage and/or displacement of adjacent tiles. The structural integrity of the

attachment system withstands normal system shocks, vibrations, brush loads, etc. Supplementary armor may be stored or transported separately from the vehicle for application in the field when enhanced  
5 armor is desired and may be selectively applied to selected portions of the vehicle, thus enhancing the versatility of the vehicle.

Other features and advantages of the invention will be seen as the following description of a  
10 particular embodiment progresses, in conjunction with the drawings, in which:

Figure 1 is a view of a light armored vehicle that incorporates survivability enhancement in accordance with the invention, the enlarged views of  
15 Figures 1A, 1B and 1C are enlarged views of parts of the vehicle as shown in Figure 1;

Figure 2 is an elevational view of an array of armor tiles in accordance with the invention;

Figure 3 is a sectional diagrammatic view of a  
20 portion of an armor tile in accordance with the invention;

Figure 4 is a sectional diagrammatic view of portions of components of the survivability enhancement system of Figure 1 is spaced-apart  
25 relation;

Figure 5 is a similar diagrammatic view of the components of the survivability enhancement system of Figure 4 in fastened relation;

Figure 6 is a graph illustrating stress/strain  
30 characteristics of a survivability enhancement system in accordance with the invention and of an adhesive bonding system; and

Figure 7 is a view, similar to Figure 1, of a light armored vehicle illustrating field replacement  
35 of armor tiles.

Shown in Figure 1 is a light weight high

mobility vehicle 10 that includes hull 12 mounted on a series of driven wheels 14, and turret 16 on hull 12. Hull 12 is constructed of 0.635 cm (one quarter inch) thick steel armor plate 18 and has fastener structure 20 on the outer surface of the steel hull. Structure 20 includes an array of upstanding hook elements 22 that are integral with base 24 and formed of injection-molded nylon, with base portion 24 secured to the surface of armor 18 with epoxy or other suitable adhesive. Hooks 22 have a height of about four millimetres, are flexible and facilitate resilient interengagement and disengagement with complementary structure of a cooperating fastener component.

Overlying fastener structure 20 is flexible cover sheet 30 which provides signature reduction (such as modified reflectivity to electromagnetic radiation, infrared radiation, or the like). Cover sheet 30 includes a silicone rubber substrate in which particulate signal reduction material 28 is embedded, sheet 30 having a thickness of about six millimetres. Secured on the inner surface of cover 30 by a suitable adhesive is fastener structure 32 which includes an array of loop elements 34 of polymeric material, the loops having heights of about three millimetres.

Hook elements 22 of fastener structure 20 may be engaged with loop elements 34 of cover 30 in top region 26 as indicated in Figure 1A. In other locations of the hull 12, one or more layers of ceramic armor tiles 40 may be interposed between hull 12 and cover 30, a single layer of armor tile 40 being provided in side region 36 as indicated in Figure 1B and a double layer of armor tile 40 being provided in front region 38 as indicated in Figure 1C. Each ceramic tile 40 is of boron carbide of

about two centimeters thickness and has a hexagonal configuration with the straight edge sections of the perimeter having a length of about eight centimetres. As indicated in Figure 4, secured on planar surface 42 of each tile 40 is fastener structure 44 similar to cover fastener structure 32, and secured on opposite surface 46 is fastener structure 48 of the hooking type similar to hull fastener structure 20. A portion of an array of armor tiles 40 secured on armor plate 18 is diagrammatically shown in Figure 2.

As indicated in Figure 3, fastener structure 48 includes base portion 50 and an array of hook elements 52, each of which includes flexible stem portion 54, deflection surface 56, and latch surface 58. It will be apparent that other hooking element configurations (of arrow or spear shape, for example) may be employed. Hooking elements 22 of the fastener structure 20 secured to hull 12 are of similar configuration. Cooperating fastener structures 32, 44 include nylon filament or metal wire loops 34 secured to base sheet 60. Fastener structures 44, 48 are secured to armor tile 40 with bonding agents 62.

Shown in Figures 4 and 5 are diagrammatic sectional views of components of the survivability

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enhancement system, the components being shown in spaced apart relation in Figure 4 and in fastened relation in Figure 5.

5       The holding force of the survivability  
enhancement fastener system is a function of the  
configuration, density and material of the hook elements  
22, (52) as well as the size, number and material of  
loops 34. In a particular embodiment, the fastener  
structures 22, 34, in attached relation, have a tension  
10       restraint of about seven psi or a total of 180 pounds  
over the 26-square inch area of an individual tile 40;  
and a shear restraint of approximately fifteen psi or a  
total of 390 pounds for the 26-square inch area of a  
tile 40. The fastener arrangement provides compliance  
15       and compression force absorbance characteristics.

Stress/strain relationship of hook-loop  
fastener arrangements subjected to lateral (shear)  
forces are indicated in the graph of Figure 6. As  
indicated by line 70, with hooks 22 (52) engaged with  
20       loops 34, the stress/strain relationship of the  
attachment force is maintained at a high level as a tile  
40 is subjected to increasing shear force, loops 34  
releasing but hooks 22 (52) picking up adjacent loops 34  
and maintaining a high level attachment effect. Thus,  
25       the attachment system has energy absorbing  
characteristics, in contrast with an adhesive, for  
example, that, as indicated by line 72 in Figure 6,  
provides resistance to shear forces up to peak 74 but  
fails when the adhesive bond is broken and then the tile  
30       40 is no longer fastened to the armor substrate 18.

With reference to Figure 2, a ballistic missile  
hit on tile 40A transfers energy to the six surrounding  
tiles 40B, and each of those immediately adjacent tiles  
40B correspondingly transmits energy to the surrounding

twelve tiles 40C. The armor system thus provides progressive energy dissipation and maintains substantial integrity of the armor.

As indicated in Figure 7, the armor tiles 40 may be supplied to the field in convenient transport containers 80. The tiles 40 in each container 80 have complementary fastener structures 44, 48 on their opposed surfaces and are readily installed on vehicle 10 in the field. For example, should tile armor 40 on front surface region 38 be damaged as indicated at 82, signature reduction cover 30 may be peeled down, and the damaged tiles removed (as with a pry tool) and replaced with substitute tiles 40 that are secured in place merely by pressing the tile 40 towards hull 12 to engage the complementary fastener structures. After tile replacement, cover 30 is resecured on the outer tile layer also by mere pressing. An auxiliary section of cover structure 30 may be secured over damage region 84 as desired. Similarly, other tiles 40 may be replaced or augmented in the field as indicated, for example, at 86 on side surface 36.

The survivability enhancement system incorporates armor tile with fastener structure that provides energy absorption and attachment that is maintained when exposed to large shear forces resulting, for example, from detonation of an explosive missile on an adjacent armor tile. Forces applied to adjacent tiles 40 may be adjusted as a function of the fastening system and are moderated by energy transfer to adjacent tiles and by the high sliding resistance of the fastener structures while not exceeding tensile or compression limits of the armor tiles 40.

While a particular embodiment of the invention has been shown and described, various modification

thereof will be apparent to those skilled in the art,  
and therefor, it is not intended that the invention be  
limited to the disclosed embodiment or to details  
thereof, and departures may be made therefrom within the  
5 spirit and scope of the invention.

**CLAIMS:**

1. An applique armor system that has energy  
absorbing characteristics and provides progressive  
5 energy dissipation comprising

fastener structure of a first type fixed on the  
surface of a vehicle or system whose survivability is  
to be enhanced, a plurality of armor tiles, each  
said armor tile having a surface, and

10 fastener structure of a second type and  
complementary to said first type fastener structure  
secured to said surface of each said armor tile, one  
of said fastener structures having a multiplicity of  
projecting hooking elements and the cooperating other  
15 fastener structure having complementary structure  
that is releasably interengaged with said hooking  
elements, each said tile having perimeter surface  
portions in mating juxtaposition with perimeter  
surface portions of adjacent tiles to provide a  
20 composite supplementary armor layer on said vehicle  
or system.

2. The system of claim 1 wherein each said  
armor tile has a planar surface to which said  
25 fastener structure of a second type is secured.

3. The system of claim 1 or claim 2 wherein  
said fastener structures in attached relation, have a  
tension restraint of at least about five psi and a  
30 shear restraint of at least about ten psi.

4. The system of any preceding claim wherein  
each said armor tile has a thickness of at least  
about one centimeter and is of polygon configuration  
35 with perimeter edge surfaces that are at least about  
four centimetres long.



5. The system of claim 4 wherein each said tile has at least five perimeter edge surface segments.

5           6. The system of any preceding claim wherein each said armor tile is a ceramic material such as boron carbide, silicon carbide, aluminium oxide or titanium boride.

10           7. The system of any preceding claim wherein each said armor tile has opposed planar surfaces, fastener structure of said first type is bonded to one planar surface and fastener structure of said second type is bonded to its opposed planar surface.

15           8. The system of any preceding claim and further including  
flexible cover structure with fastener  
structure of said second type secured to the inner  
20 surface of said cover structure for fastening  
interengagement with fastener structure of said first type.

25           9. The system of claim 8 wherein said cover structure includes signature reduction characteristics.

30           10. The system of claim 9 wherein said cover structure is of silicone rubber material and has particulate signal reduction material embedded in it.

35           11. The system of any preceding claim wherein each said hooking element of said one fastener structure includes a stem portion and a head portion that projects laterally from one side thereof for engaging a portion of the cooperating fastener



structure of said second type in fastening relation.

12. The system of any preceding claim wherein  
said one fastener structure is an integral member of  
5 molded thermoplastic polymeric material that includes  
said hooking elements and a base portion, and said  
base portion is adhesively bonded to the surface on  
which it is mounted; and said second fastener  
structure includes a multiplicity of loop portions  
10 releasably interengaged with said hooking elements.

13. An armor system substantially as described  
with reference to and as illustrated in the  
accompanying drawings.

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14. A vehicle having armor substantially as  
described with reference to and as illustrated in the  
accompanying drawings.

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