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United States Patent

Alliegro et al.

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[54] **RECOMPOSITE CERAMIC ARMOR WITH METALLIC SUPPORT STRIP**

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[22] Filed: **May 12, 1967**

[21] Appl. No.: **638,009**

[52] **U.S. Cl.**.....**109/83,** 161/404
[51] **Int. Cl.**.....**F41h 5/04,** F41h 5/26
[58] **Field of Search**.....89/36, 36 A; 109/79, 80, 81, 109/83, 82; 161/404; 2/2.5

[56] **References Cited**

UNITED STATES PATENTS

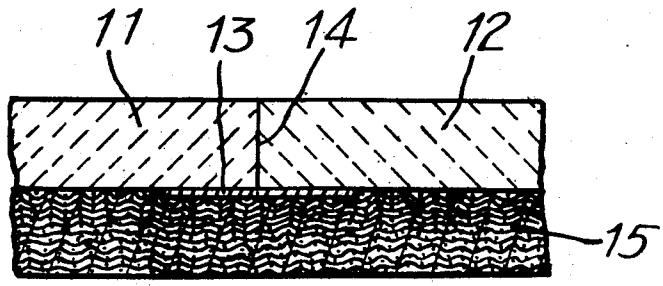
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[57] **ABSTRACT**

Carbon steel, alloy steels, titanium strips, directly under the joints and free edges of the ceramic face plates of ceramic composite armor improves performance of the armor; metal strips should be 0.5 to 1.5 inches in width, from 0.010 inches to 0.125 inches in thickness, and have a modulus of elasticity of at least 5 million p.s.i.

6 Claims, 2 Drawing Figures



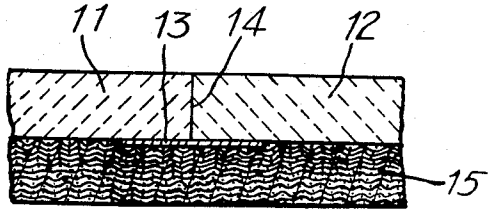


FIG. 1

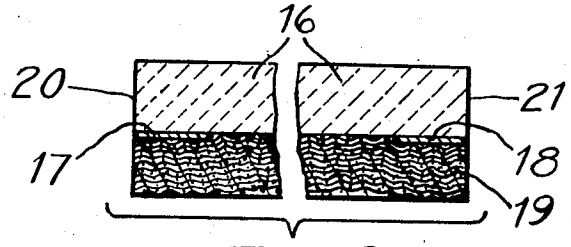


FIG. 2

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RECOMPOSITE CERAMIC ARMOR WITH METALLIC SUPPORT STRIP

BACKGROUND OF THE INVENTION

Recently light weight composite armor for protection against small arms fire has been developed by employing hard brittle ceramic facing material to the back of which is bonded a glass fiber laminate of woven glass cloth and consisting of several laminations held together by a resinous bond. When ceramic armor is hit, its high strength and hardness, and in particular its high modulus of elasticity, come into play in starting to defeat the projectile. Extremely high loading rates are applied to both the projectile and the ceramic. When the stiffness of the ceramic is sufficient to overload the projectile beyond its yield point causing it to fracture, before the ceramic itself yields fully, the projectile will be stopped. If the ceramic yields first, the projectile will not be damaged sufficiently to initiate the orderly expansion of the load area to the backup and a penetration will occur. This expanded high load area is absorbed through an orderly delamination of the backup material, generally a resin-starved fiberglass laminant of from 10 to 24 layers.

This idealized system exists in a given area within an armor panel, that is, a percentage of the total area will offer optimum protection. As edges, corners, and boundaries of abutting plates are approached, ballistic performance will degrade. In the case of a 6 inch × 6 inch tile, roughly 60 percent will be substandard, a 12 inch × 12 inch tile, roughly 30 percent, and a 15 inch × 15 inch, roughly 20 percent. The technology of going to large shapes has been realized, but the need for 100 percent optimum protection is a real one and has not been attained.

Presently, "raised edges" are put on one ceramic system to strengthen the susceptable area and thus improve its performance. This is a partial solution; problems exist in making a reliable raised edge plate at a low rejection level, limiting economic gains. Also there is a practical limit to the differential between raised edge and center tile thickness, contributing to the center sections being over-designed, thus adding to the systems weight. Keeping weight to a minimum is required since ceramic armor systems are used to protect personnel (which means wearing the armor) and helicopters, craft which are supersensitive to weight additions. Weight costs in both areas have been expressed in terms of from $50 to $300 a pound, lending impetus to the quest for the lightest armor possible.

DESCRIPTION OF THE INVENTION

Ceramic composite armor systems can be improved at the joints and edges by adding a thin ribbon of metal between the ceramic and the fiber backing as shown in the drawings in which:

FIG. **1** shows a cross-sectional view of a joint in an armor system; and

FIG. **2** shows a cross-sectional view of reinforced edges in an armor system.

In FIGS. **1**, **11** and **12** are adjacent ceramic tiles which form the facing of the armor, **13** is a metal strip extending along the full length of joint **14**, and **15** is the glass fiber laminate backing material bonded to the facing **11** and **12**.

In FIG. **2**, **16** is the ceramic facing plate, **17** and **18** are metal strips extending along the full length of the **20** and **21** of the plate **16**, and **19** is the fiber laminate backing bonded to the plate **16**.

The facing ceramic plates may be monolithic shapes of alumina, silicon carbide, or boron carbide, The facing may be flat or curved depending upon the particular employment of the armor. The following is an example of a flat armor made up of a plurality of adjacent boron carbide tiles, in which the improvement of the present invention is provided at both the joints between the tiles and at the free edges of the whole plate. The invention may be applied to other shapes and systems, such as single piece breast plates in which the metal strip is provided along all the free edges, or systems in which the ceramic facing is monolithic polycrystalline alumina, or monolithic polycrystalline silicon carbide.

EXAMPLE

Two 12 inch by 12 inch square flat tiles of polycrystalline monolithic boron carbide, 0.340 inches thick, are butted together along one edge. A steel strip 1 inch wide by 1 foot long is bonded to the tiles along the joint by a polysulfide resin or other suitable adhesive such as a polyurethane. The steel is oil hardening ground flat stock, SAE Type 01 (Marshall OILcrat), 0.030 inches in thickness. Additional strips of the same steel are bonded along the outer edges of the two plates. A woven glass fiber backing consisting of 12 layers of woven roving glass fiber bonded with 25 percent by weight of polyester resin bond (¼ inch thick laminate, made from 23 ounce per yard, 1,000 pound per inch of width tensile strength warp yarn, and 800 pound per inch of width tensile strength filling yarn; tensile strength of laminate being 45,000 to 50,000 pounds per square inch; interlaminar shear strength of laminate being 1,000 to 1,300 pounds per square inch) is bonded to the side of the ceramic plates to which the steel strips are attached by a polysulfide resin (Pro-Seal 890B, sold by Coast Pro-Seal & Mfg. Co., Los Angeles, California. The assembly is clamped and cured for 3 days without heat or for 4 hours at 220° F. Other non-brittle adhesives can be used such as commercially available polyurethanes.

The completed composite armor plate, upon subjection to ballistic tests shows no substantial reduction of protective action at the joints or at the edges, as compared to the protection offered by the central portions away from joints and edges.

Although we have illustrated a carbon steel as a reinforcing material in the example, alloy steels and titanium may be used. The support strip must be metallic in nature and must have a modulus of elasticity of at least 15×10^6 p.s.i. Because of the lower mass per unit volume for titanium as compared to steels, the thickness of the strip, when titanium is used should be roughly 1.5 times the thickness of an equivalent steel strip. Whatever metal is used a thickness of 0.125 inches should not be exceeded, and a minimum thickness of 0.010 inches is required for significant improvement. A thickness of 0.015 inches to 0.060 inches is preferred and a width, at the joints of from 1 to 1.5 inches is found most useful. At the free edges the width may be reduced to 0.5 inches, producing an overlap of 0.5 inches as in the case of joint protection when a 1 inch strip is used.

What is claimed is:

1. In a composite armor having a ceramic facing and a bonded laminate fibrous backing, the improvement consisting of: a metal strip, at least 0.5 inches wide and at least 0.010 inches thick along the outer edges of the armor between the facing and the backing, said metal having a modulus of elasticity of at least 15×10^6 pounds per square inch.

2. In a composite armor having a ceramic facing and a bonded laminate fibrous backing in which the ceramic facing is made up of at least two plates butted together to form a joint, the improvement consisting of a metal strip at least one inch wide, along the joint, positioned between the facing and the backing, said metal strip having a thickness between 0.010 and 0.125 inches and a modulus of elasticity of at least 15×10^6 pounds per square inch.

3. The armor of claim 1 in which the metal is selected from alloy steels, carbon steels, and titanium.

4. The armor of claim 2 in which the metal is selected from the group consisting of alloy steels, carbon steels, and titanium.

5. The armor of claim 4 in which the facing plate is selected from the group consisting of boron carbide, alumina, and silicon carbide.

6. The armor of claim 5 in which the metal is a carbon steel having a modulus of elasticity of 15×10^6 pounds per square inch and a thickness of 0.030 inches.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3683828 Dated August 15, 1972

Inventor(s) Richard A. ALLIEGRO and Addison W. LEARNED III

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

The title of the patent should read: --- COMPOSITE CERAMIC ARMOR WITH METALLIC SUPPORT STRIP --- .

The assignment to NORTON COMPANY dated May 9, 1967 and recorded June 16, 1972 on Reel 2865, Frame 216.

Signed and sealed this 6th day of February 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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