United States Patent [19]

Dörre

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[54] **CERAMIC REINFORCED HELMET**

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[52] **U.S. Cl.** .... **2/6,** 89/36 D, 117/46 FB, 161/404, 89/36 A;36 D

[51] **Int. Cl.** **F41h 1/06**

[58] **Field of Search** .... 2/6, 5, 3 R, 2.5; 109/82; 161/404; 29/191.2, 194, 196.1, 196.6, 195 A; 117/105.2, 93.1 PF, 46 FB

[56] **References Cited**

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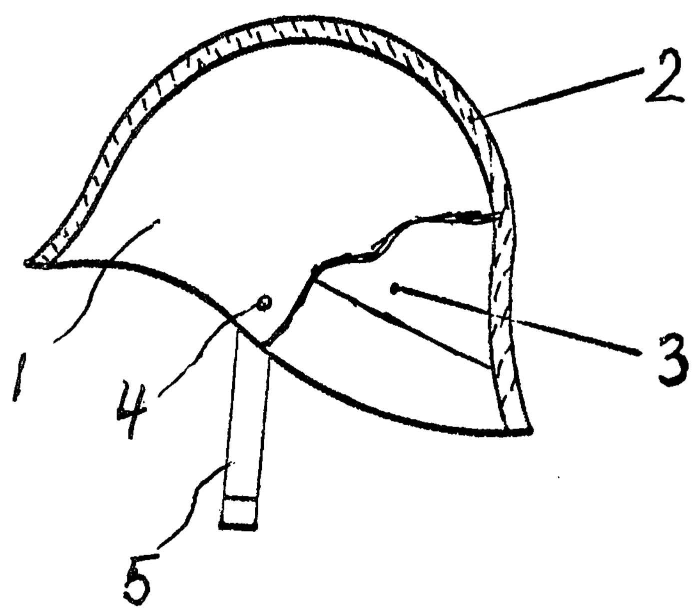
Primary Examiner—Werner H. Schroeder
Attorney, Agent, or Firm—Hans Berman

[57] **ABSTRACT**

A steel helmet may be strengthened greatly by coating its outer, generally convex face with a layer of ceramic particles deposited on the steel at a temperature above their sintering temperature, as by flame spraying or plasma spraying, if the ceramic material has a hardness value of at least 8 on the Mohs scale. Chromium sesquioxide when integrally bonded to the steel of the helmet is strongest at light weight, but aluminum oxide and the carbides of boron, titanium, or silicon perform almost as well. The laminar helmet shell resists projectiles that would pass through an equal weight of steel alone.

7 Claims, 3 Drawing Figures



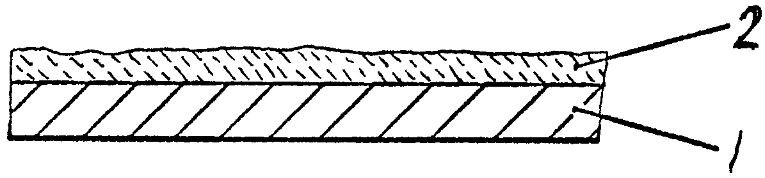


Fig. 2

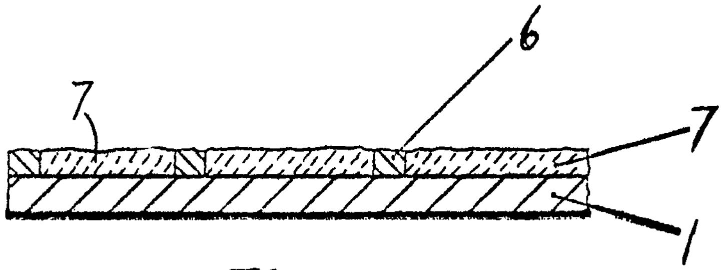


Fig. 3

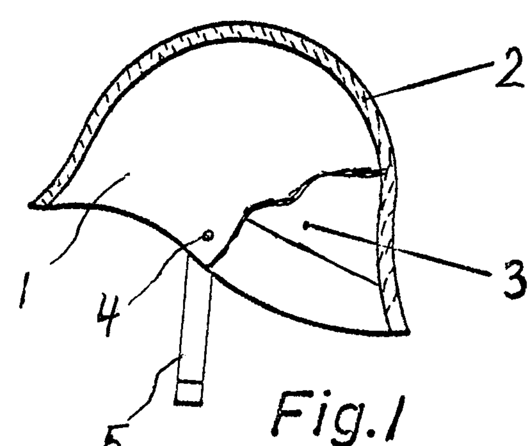


Fig. 1

CERAMIC REINFORCED HELMET

This invention relates to the protection of the human body from flying projectiles such as bullets, and particularly to protecting devices which are hollow shells of arcuate cross section in three planes perpendicular to each other.

It has been disclosed in German Pat. Nos. 1,265,621 and 1,213,305 that composite armor plates having layers of steel and sintered alumina are more effective against high-powered projectiles than steel plates of equal weight, and may be employed for protecting armored vehicles. When the cermic layer is directed toward an incident projectile, much of the kinetic energy of the latter is consumed in breaking the intercrystalline bonds of the sintered material before the projectile reaches the steel.

The devices of the prior art have been found effective in the applications for which they were intended, but they are not readily applicable where they need to assume a three-dimensionally curved shape. Body armor, helmets, spherically curved shields, and three-dimensionally curved parts of a vehicle body were not available in a practical manner from the teachings of the older patents.

It has now been found that helmets and other devices may be effective for impeding the flight of a projectile, such as a bullet from a heavy police gun at close range, if the device has a laminar shell including a metallic base layer and an outer layer of non-metallic, ceramic material even if the shell is of substantially uniform thickness and of arcuate cross section in three planes perpendicular to each other. To achieve adequate protection under these conditions with a helmet of practical weight, it is necessary that the ceramic layer be located on the outer, substantially convex face of the base layer, and that it essentially consist of crystalline particles having a hardness value of at least 8 on the Mohs scale and integrally bonded to each other and to the metallic base layer by contact at a temperature at least equal to the sintering temperature of the ceramic material.

Other features, additional objects, and many of the attendant advantages of this invention will readily become apparent from the following detailed description of preferred embodiments when considered in connection with the appended drawing in which:

FIG. 1 shows a helmet of the invention in side elevation, its outer layers being partly removed to show internal structure;

FIG. 2 illustrates the helmet of FIG. 1 in fragmentary cross section; and

FIG. 3 shows a modification of the helmet of FIG. 1 in the manner of FIG. 2.

Referring now to the drawing, the initially to FIG. 1, there is seen a helmet having a steel base layer 1, almost all portions of which are three-dimensionally curved, that is, three reference planes can be made to intersect each other in any portion of the steel layer 1 in such a manner that the helmet is of arcuate cross section in each of the three planes. The outer face of the steel layer, which solely visible in FIG. 1, is convex over most of its area, and the steel is of practically uniform thickness so that almost the entire inner face of the helmet, mostly obscured in FIG. 1, is concavely arcuate.

The outer face of the helmet carries a ceramic layer 2 which normally covers the entire convex steel surface. A plastic liner 3 is fastened in the vacity of the laminar shell of steel and ceramic material conformingly to receive the top of a human head, as is conventional in itself. Rivets 4 pivotally secure a chin strap 5 to the base layer 1 of the helmet, and permit the helemt to be fastened to the head of a wearer.

The non-metallic ceramic layer 2 preferably consists of sintered chromium sesquioxide particles which are integrally bonded to each other and to the convex outer face of the steel layer 1 by contact at a temperature above the sintering temperature of the chromium oxide under at least minimal pressure. The ceramic layer 2 is preferably produced by discharging the chromium oxide particles against the carefully cleaned convex steel surface from a flame spraying gun or a plasma gun, which are staple articles of commerce.

The appearance of the two layers after spraying by means of a plasma gun is represented in FIG. 2 which, for the convenience of pictorial representation, shows the surfaces of the layer 1 to be rectilinear in the chosen section. The ceramic layer 2 is firmly and directly bonded to the steel surface. The exposed ceramic surface shows a somewhat irregular contour characteristic of a layer deposited from a plasma above the minimum sintering temperature in the form of individual particles, and other features characteristic of the method of deposition can readily be detected in the sectioned ceramic material under amicroscope. The metal surface adjacent the ceramic material, while appearing straight and smooth on the scale of FIG. 1 and in cross section, shows a peening pattern at higher magnification and particularly in plan view after removal of the ceramic layer.

If the helmet base shown in FIG. 1 is made of alloy steel having a tensile strength of at least 100 kp/mm^2, such as commerically available high-strength steel containing nickel, zirconium, and molybdenum as principal alloying elements, and of a thickness to give it the weight of a conventional military or police helmet, its bullet resistance is greatly increased by an outer layer of chromium sesquioxide, only 3 millimeters thick, and thus not materially increasing the weight of the helmet. Even if the thickness of the basic steel layer is reduced to make the combined wieght of the steel and ceramic layer 1, 2 equal to the weight of the steel shell in the convventional helmet, the protection afforded by the device of the invention is far superior.

The strength of the bond between the metallic and ceramic layers directly affects the bullet resistance of the helmet. The ceramic layer is cracked at the point of impact, and a shock wave is propagated in the ceramic material at the speed which sound has in the same material. The initially formed crack also spreads, but at a lower speed so that the front of the shock wave travels continuously through intact ceramic material, and its energy is dissipated as work done in separating the sintered particles from each other. The amount of work required depends in part on the backing the bonded ceramic particles in the line of crack growth receive from other ceramic particles, and it is apparent that such backing depends to a significant extent on the strength of the bond between the ceramic and metal layers. A conforming shell of ceramic material loosely superimposed on a steel shell is not nearly as effective as the same thickness of ceramic material applied by flame spraying, and a plasma sprayed ceramic coating is again superior to a coating deposited by flame spraying at lower temperature.

Yet, even a ceramic layer bonded to the basic steel layer by means of a plasma gun may be cracked over the entire surface of the helmet shown in FIG. 1 by the impact of a single projectile of high energy. The helmet may still prevent injury to the wearer by the projectile, but the effectiveness of the helmet in impeding injury by a subsequent projectile is seriously impaired.

The ability of a helmet of the invention to protect the wearer against a succession of projectiles can be improved by providing the steel layer **1** with ribs **6** welded or otherwise fixedly fastened to the outer, generally convex surface. The ribs **6** may be flush with the ceramic layer, as illustrated, or project from the latter to divide spacedly juxtaposed portions **7** of the ceramic material from each other. The steel ribs interfere with crack propagation from one ceramic portion to the other in a manner closely correlated to the temperature at which the ceramic material was deposited on the steel. Cermaic coatings deposited from a plasma gun benefit most from ribs of the type illustrated in FIG. **3** which may intersect each other frequently enough so as to bound ceramic layer portions only two inches square.

Other refractory ceramic materials may be employed instead of chromium sesquioxide for coating the metallic base layer of a laminar helmet shell. Aluminum oxide and the carbides of boron, titanium, and silicon are applied in the same manner as chromium sesquioxide and produce similar results depending on their hardness. Zirconium oxide and tungsten carbide also are capable of application by plasma gun and greatly enhance the bullet resistance of a steel helmet. However, their specific gravity is substantially higher than that of the preferred coating materials. Various, very hard, refractory nitrides, borides, and silicides are available and operative, but not practical at this time partly for economical reasons, and partly because of inadequate corrosion resistance for outdoor use.

Where the protection afforded by conventional steel helmets is adequate, satisfactory protection can be had from helmets of the invention of much smaller weight whose base layer consists of aluminum alloys, particularly the high-strength aviation alloys containing zinc and magnesium as primary alloying ingredients, such as Type AA 7075 whose tensile strength is better than 40 kp/mm^2, and which are thus superior in strength to an equal weight of the alloy steels mentioned above. A very strong bond is formed by the aluminum alloys with the aforedescribed ceramic particles deposited at or above their sintering temperature from conventional flame spraying equipment or from a plasma gun.

While the invention has been described with reference to a helmet, it is not limited thereto. The modes of propagation of a shock wave and of cracks in three-dimensionally curved layers of sintered ceramic are thought to be different from those in planar layers so that the strength of the bond between a metallic base layer and the superposed ceramic layer is significant to an extent not observed in planar laminates. A cermaic layer laid down on a metal base in the from of particles at or above their sintering temperature thus provides resistance to flying projectiles not available otherwise with an equal weight of material at comparable cost.

It should be understood, of course, that the foregoing disclosure relates only to preferred embodiments of the invention, and that it is intended to cover all changes and modifications in the examples of the invention herein chosen for the purpose of the disclosure which do not constitute departures from the spirit and scope of the appended claims.

What is claimed is:

1. A helmet comprising a laminar shell of substantially uniform thickness and of arcuate section in three planes perpendicular to each other, said shell including a metallic base layer having an outer, substantially convex face and an inner, substantially concave face, and an outer layer of ceramic material on said convex face, said outer layer essentially consisting of crystalline, non-metallic particles having a hardness value of at least **8** on the Mohs scale and being integrally thermally bonded to each other and to said base layer.

2. A helmet as set forth in claim **1**, wherein the material of said base layer is alloy steel having a tensile strength of at least 100 kp/mm^2.

3. A helmet as set forth in claim **1**, wherein the material of said base layer is an aluminum alloy having a tensile strength of at least 40 kp/mm^2.

4. A helmet as set forth in claim **1**, wherein said ceramic material is aluminum oxide, chromium sesquioxide, boron carbide, titanium carbide, or silicon carbide.

5. A helmet as set forth in claim **4**, wherein said outer layer includes a plurality of portions offset from each other, the devise further comprising at least on rib of metallic material extending outward from said convex face and separating said portions.

6. A helmet as set forth in claim **4**, further comprising a liner in said shell dimensioned conformingly to receive the top of a human head, and a chin strap fastened to said shell for securing the latter to said head when the head is received in said liner.

7. A helmet as set forth in claim **6**, wherein the material of said base layer is alloy steel having a tensile strength of at least 100 kp/mm^2.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,871,026 Dated March 18, 1975

Inventor(s) ERHARD DÖRRE

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

In the heading, after line [21] insert --

[30] Foreign Application Priority Data

Dec. 17, 1971 Germany .... P 21 62 692.6 --

Signed and Sealed this

twenty-ninth Day of July 1975

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

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