United States Patent

[11] 3,599,573

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[21] Appl. No. 733,596
[22] Filed May 31, 1968
[45] Patented Aug. 17, 1971

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[54] **COMPOSITE PREFORMED PENETRATORS**
9 Claims, 4 Drawing Figs.

[52] U.S. Cl. 102/92.4
[51] Int. Cl. F42b 11/00
[50] Field of Search 102/92.4, 52

[56] **References Cited**

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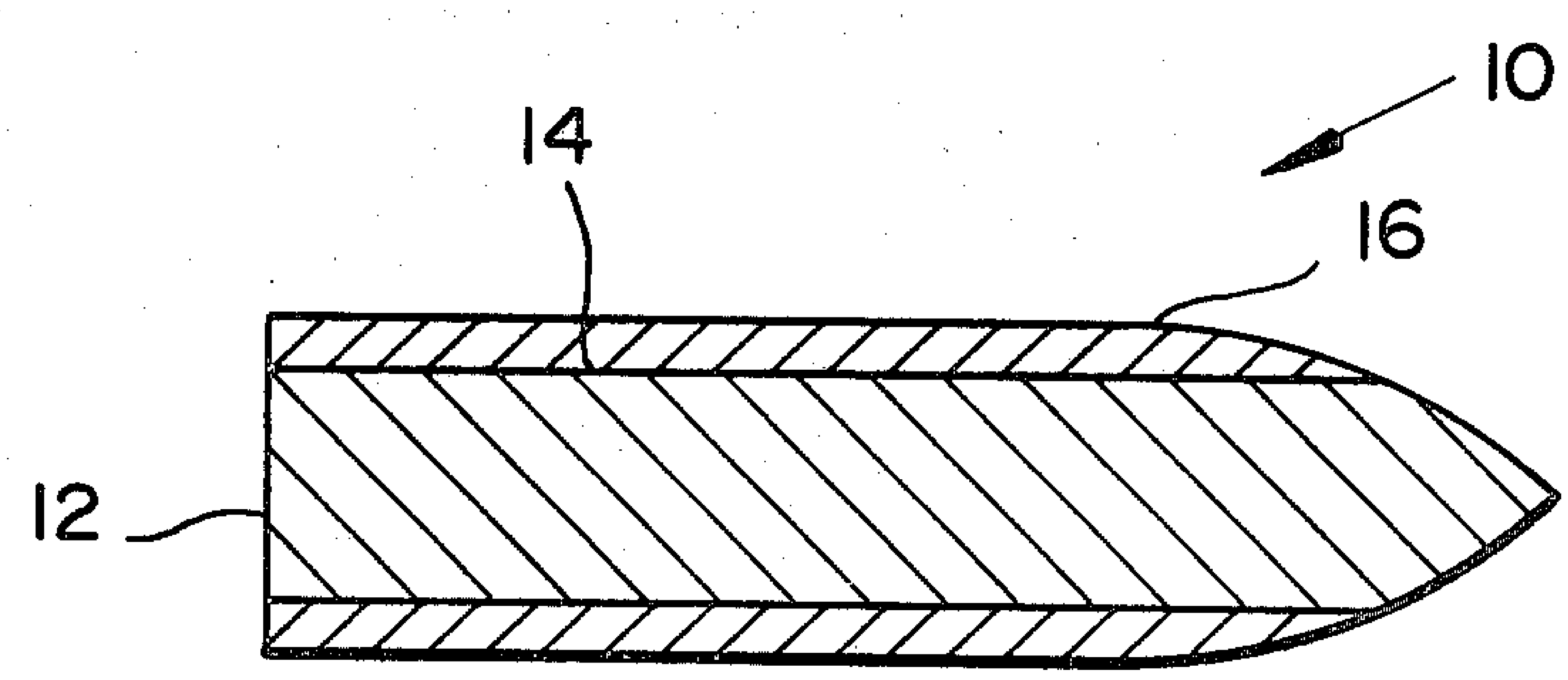
ABSTRACT: An improved armor-piercing projectile has a hard but brittle inner core metallurgically bonded to a tough but ductile outer shell which protects the core from brittle fracture on impact. The bimetallic structure of the projectile provides a higher penetration ability against "hard-faced" armor plate for a given size projectile than heretofore obtainable with homogeneous projectiles.



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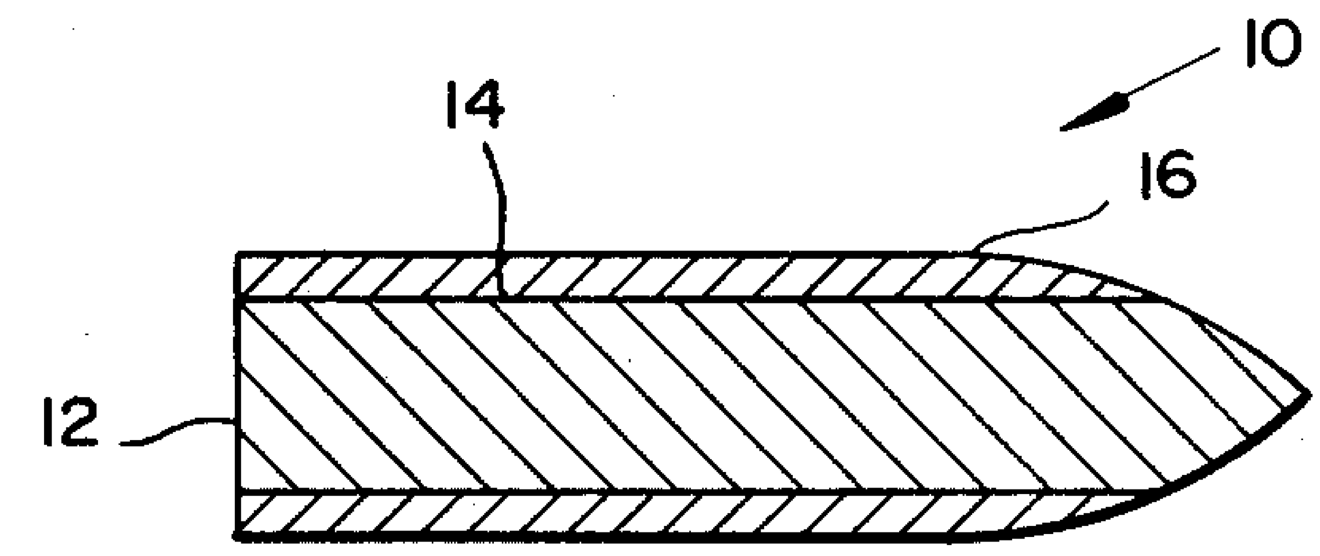

FIG. 1

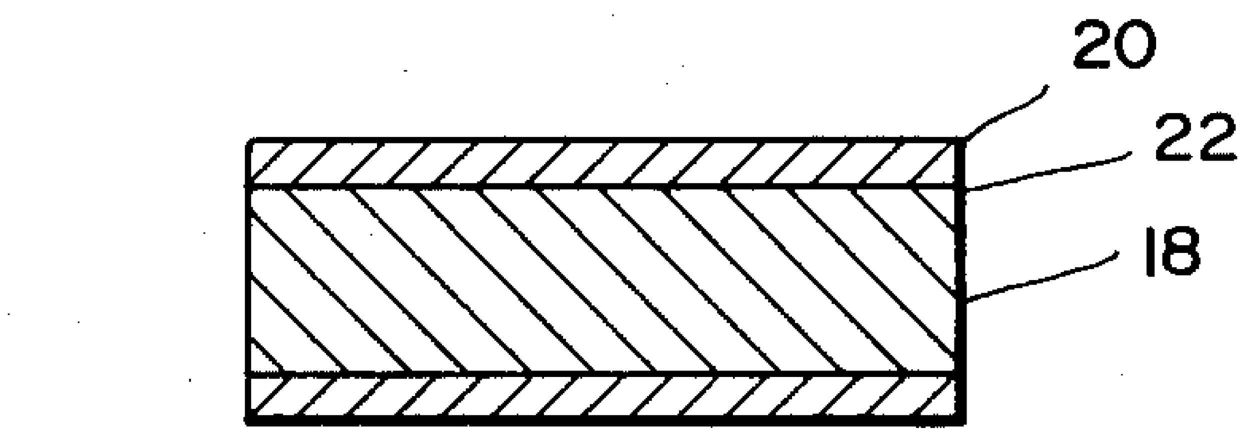

FIG. 2

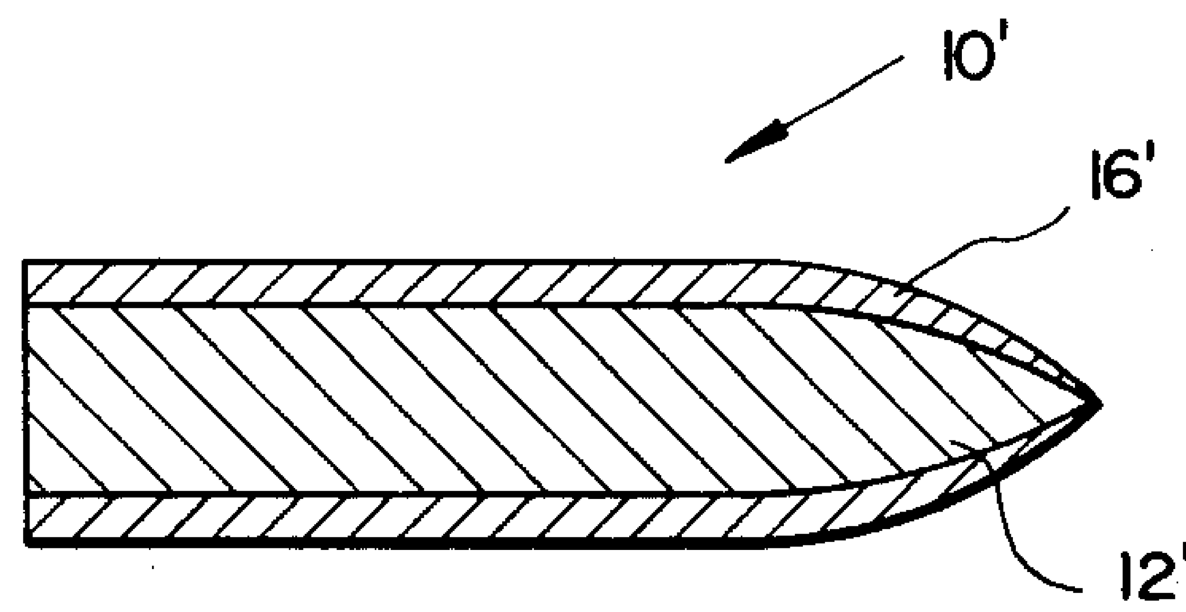

FIG. 3

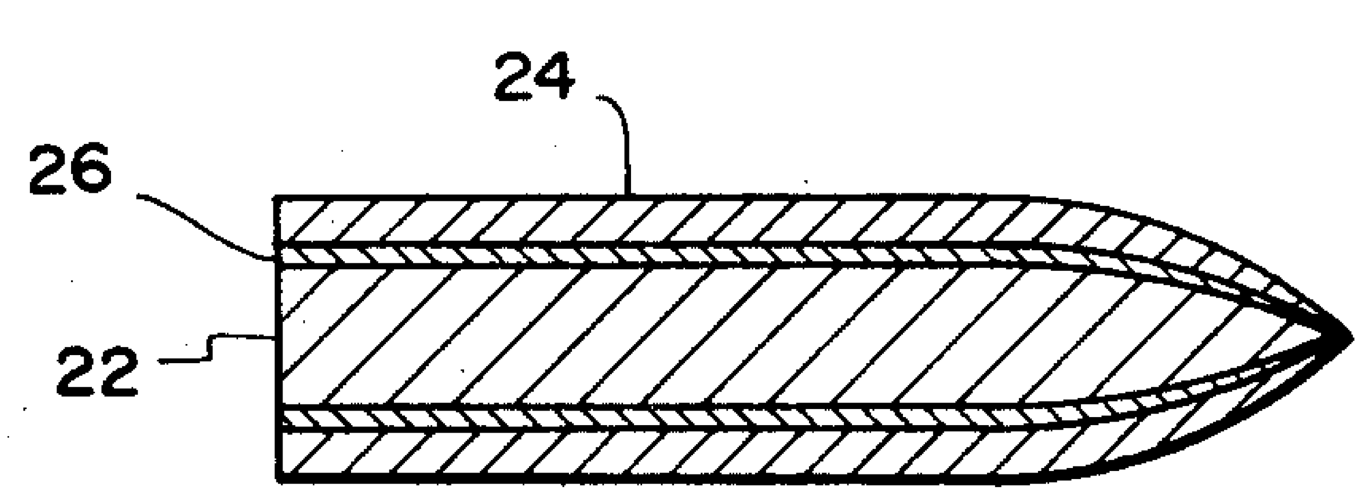

FIG. 4

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COMPOSITE PREFORMED PENETRATORS

BACKGROUND OF THE INVENTION

The term "projectile" as used herein denotes a solid-core object which is fired against a target at high velocity in order to destroy it. The projectile generally has an aerodynamic shape so as to offer minimum resistance to motion through a fluid medium such as air through which it travels on its way to the target. At present, such projectiles are machined from homogeneous steel alloys. Projectiles of this type can be made relatively effective when utilized against conventional armor plate.

Recently, however, hard-faced armor plate has been developed which provides far higher ballistic resistance per unit weight to such projectiles than was heretofore available with conventional armor plate. Hard-faced armor plate is formed from an outer layer of a hard metal or ceramic bonded to an inner layer of a softer and tougher metal which provides cohesive support for the outer layer. The effectiveness of hard-faced armor plate arises from the fact that conventional projectiles of very ductile material (such as lead) completely fail to penetrate the outer layer of the armor plate due to the softness of the projectile material in contrast with the hardness of this outer layer, while conventional armor-piercing projectiles of a harder material (such as a tool steel), which might be expected to penetrate the armor plate, generally fracture on impact with it due to the brittleness of the projectile material. Thus, the effectiveness of homogeneous projectiles has been greatly lessened by the advent of the newer hard-faced composite armor plate.

BRIEF SUMMARY OF THE INVENTION

Accordingly, it is an object of my invention to provide an improved armor-piercing projectile.

Another object of my invention is to provide an armor-piercing projectile having improved resistance to brittle fracture.

Yet another object of my invention is to provide an improved armor-piercing projectile which has increased penetrability against hard-faced armor plate.

Still a further object of my invention is to provide an armor-piercing projectile of relatively high density having increased resistance to brittle fracture.

In accordance with my invention, I provide an armor-piercing projectile of improved characteristics by metallurgically bonding a tough but ductile outer shell onto a hard but brittle solid core. The ductile outer shell provides sufficient toughness to the projectile to hold the brittle core together and to prevent its fracture on impact. Thus, the hard core is maintained intact when penetrating the armor plate.

The invention accordingly comprises a product possessing the features, properties, and characteristics to be hereinafter described, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing, in which:

FIG. 1 is a longitudinal cross section of an armor-piercing projectile formed in accordance with my invention;

FIG. 2 is a longitudinal cross section of a clad billet from which the projectile of FIG. 1 may be formed;

FIG. 3 is a longitudinal cross section of a projectile of the type shown in FIG. 1 which has been modified to have its frontal portion completely covered by the outer cladding material; and

FIG. 4 is a longitudinal cross section of an alternative armor-piercing projectile having a barrier shell interposed between the solid core and the outermost shell to prevent undesirable diffusion reactions between these two.

SPECIFIC DESCRIPTION OF THE INVENTION

FIG. 1 shows an armor-piercing projectile **10** having a central, solid core **12** of a first material bonded along an interface **14** to an outer shell **16** of a second material. The forward tip of the core **12** is formed in an ogive shape for minimum aerodynamic drag during propulsion of the projectile through a fluid medium such as air. The ogive shape also assists in penetration of the object against which the projectile impacts.

The core **12** is formed from a hard but brittle material while the outer shell **16** is formed from a ductile but tough material. For example, the core **12** may advantageously be formed from a hard tool steel having a hardness on the Rockwell C scale of from 58 to 67 and preferably in the range of from 60 to 65. The shell **16** may then be formed from a milder steel such as an AISI-4620 steel having a hardness on the Rockwell C scale of from 47 to 56 and preferably from 50 to 53. Other ductile materials such as zirconium and unalloyed uranium may also advantageously be used for the shell while high density materials such as uranium alloys and tungsten may be utilized for the core. Since ceramics and metallic oxides may also be used in forming a projectile according to my invention, I shall utilize the term "metal-based" materials in the claims to denote both metals and inorganic nonmetals such as ceramics and oxides.

The dimensions of the projectile and the relative percentages of each of the materials used in it depends on the materials utilized and the application to which the projectile is to be put. Experiment shows that the hard inner core should occupy at least **40** percent of the total volume of the shell and preferably more than **50** percent in order to provide armor-piercing characteristics superior to those of conventional projectiles. This means that the ductile outer shell will occupy no more than **60** percent of the volume of the projectile and preferably less.

The projectile **10** of FIG. **1** is readily formed by any of a number of pressure-forming operations followed by subsequent finishing operations. For example, the core and shell may be roll-bonded or extrusion-bonded to each other. Generally, extrusion-bonding is preferable since it is capable of relatively quickly providing a large quantity of projectile material of uniform cross section having a good metallurgical bond between the core and the shell. Accordingly, the formation of the projectile of FIG. **1** by means of an extrusion process will now be described.

As a first step in forming the projectile, a solid, cylindrical core **18** of hard but brittle material is snugly mechanically fitted inside a tubular shell **20** of the desired ductile but tough outer material as illustrated in FIG. **2** of the drawing. At this stage, the two materials laterally contact each other along an interface **22**; the materials touch each other at this interface but are not yet bonded to each other along it. The assembled shell and core are then prepared for extrusion through an extrusion die in a known manner. For example, depending on the types of materials utilized, the shell and core may be inserted in a protective extrusion canister of mild steel and heated to an elevated temperature prior to extrusion. The materials are then extruded through a die which provides a reduction in cross section of at least 3 to 1 and preferably greater. This causes the shell and core to form a metallurgical bond with each other to thereby form an integral structure. After removal of the canning material by machining or by chemical removal, heat-treating and cleaning operations are undertaken to obtain a good finish on the outer shell. The integral shell and core are then cut into such lengths as may be convenient for each projectile to be formed. Next, the frontal portion of each projectile is machined into an ogive as illustrated in FIG. **1** to lower the aerodynamic resistance of the projectile and to increase its penetration ability. The projectile **12** is then ready for use.

It will be noted from FIG. **1** that the outer shell **16** does not completely enclose the forward portion of the projectile **10**, but instead, leaves a portion of the tip uncovered. In projectiles having cores of relatively small diameter as compared to the outside diameter of the shells, the exposed tip can readily penetrate even tough armor plate without very much danger of brittle failure. As the diameter of the core increases in relation to the outside diameter of the shell, however, the danger of brittle fracture of the exposed core tip also increases. In such cases, it is necessary to protect the tip of the brittle material by means of the outer cladding of ductile material. This may readily be accomplished by swaging the forward portion of the projectile in the area of the ductile cladding in order to spread the cladding over all, or a substantial portion of, the tip of the projectile. The resultant structure then assumes the form shown in FIG. 3 in which the projectile **10'** has a core **12'** which is totally encased both laterally and forwardly by the ductile material **16'**.

In some cases it might be desirable to use materials for the core and the outer shell which are not compatible with each other in the sense that they will not form a good or stable bond with each other. In such cases it is necessary to interpose between the core and the shell a barrier layer which is compatible with both of them. For example, FIG. 4 shows a core **22** formed from a material such as uranium which is integrally bonded to a material **24** such as steel by means of an intermediate barrier layer **26** of zirconium. The core **22** and the shell **24** are not directly compatible with each other insofar as forming a good metallurgical bond is concerned; however, they are both compatible with the layer **26**. The protective layer **26** need only be a few thousand atomic units thick.

The projectile shown in FIG. 4 is formed in the same manner as the projectile of FIG. 1, that is, the inner, solid, cylindrical core **22** of hard but brittle material is mechanically fitted inside the thin shell **26** of protective material which in turn is fitted inside the tubular shell **24** of a tough but ductile material. The resultant structure is then coextruded, machined to the desired shape, and finally heat treated. A swaging operation may then be utilized to obtain the desired distribution of the cladding material around the forward tip of the projectile as was the case with the projectile of FIG. 3.

From the above it will be seen that I have provided an improved projectile. This projectile has increased armor-piercing capabilities as contrasted to conventional (homogeneous) projectiles and does not suffer from brittle failure upon impact as would normally be the case with conventional projectiles formed from a homogeneous hard material. Further, the ability to use brittle cores without danger of brittle fracture means that materials of much greater density than heretofore possible can be used in the projectiles, thus leading to increased ballistic efficiency and penetration capability.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above article without departing from the scope of the invention, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

I claim:

1. An armor-piercing projectile having improved resistance to brittle fracture upon impact with a target, comprising:

a core comprising a generally cylindrical section and an ogival head section, said core consisting of a brittle metal-based material having a Rockwell C hardness between about 58 and about 67; and

an outer shell of a ductile, metal-based material having a hardness on the Rockwell C scale between about 47 and about 56, said outer shell being metallurgically bonded to said core along said generally cylindrical section.

2. A projectile according to claim **1** which includes an additional layer of material intermediate the core and the shell and metallurgically bonded to the core and the shell.

3. A projectile according to claim **1** in which both said materials are metals.

4. A projectile according to claim **6** in which the core is formed from a tool steel and the shell is formed from a low-carbon steel.

5. A projectile according to claim **1** in which the core is formed from a material of high density relative to the density of the shell material.

6. The projectile of claim **1** wherein said outer shell extends over said ogival head section.

7. The projectile of claim **1** in which the outside diameter of said projectile is less than twice the diameter of said core along said generally cylindrical section.

8. The projectile of claim **1** in which said core occupies at least about **40** percent of the total volume of said projectile.

9. The projectile of claim **1** in which said metal-based material of said core is an alloy selected from the group consisting of tungsten and uranium and in which said metal-based material of said shell is selected from the group consisting of uranium and zirconium.