

United States Patent

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This application June 9, 1969, Ser. No. 831,688

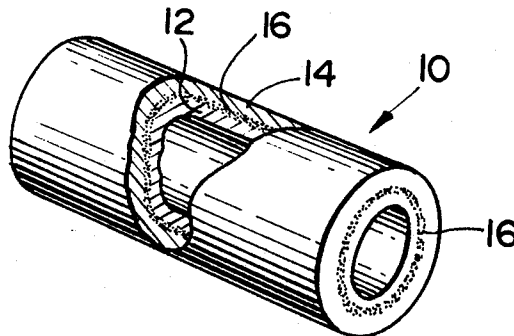
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244/1, 85, 85.5, 135; 72/258; 109/1, 49.5;
138/141, 142, 143, 153, 172, 178; 161/404

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[54] **TUBULAR, SEAMLESS, DUAL-HARDNESS ARMOR PLATE**
4 Claims, 5 Drawing Figs.

[52] U.S. Cl..... **89/36,**
72/258, 89/16, 109/1, 138/143, 161/404, 244/135
[51] Int. Cl..... **F16l 9/19**

ABSTRACT: Seamless, dual-hardness, tubular armor plate is formed from a brittle impact-resistant outer shell metallurgically bonded to a ductile inner shell by coextrusion of the two shells. Central hollow cores of either simple or complex shape are readily formed. The resultant structure has superior resistance to impact as compared to homogeneous cylinders or welded bimetallic cylinders.



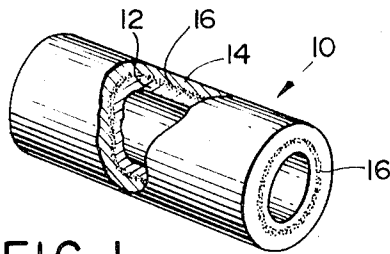


FIG. 1

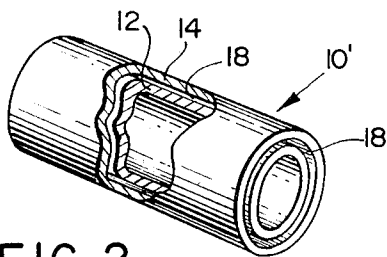


FIG. 2

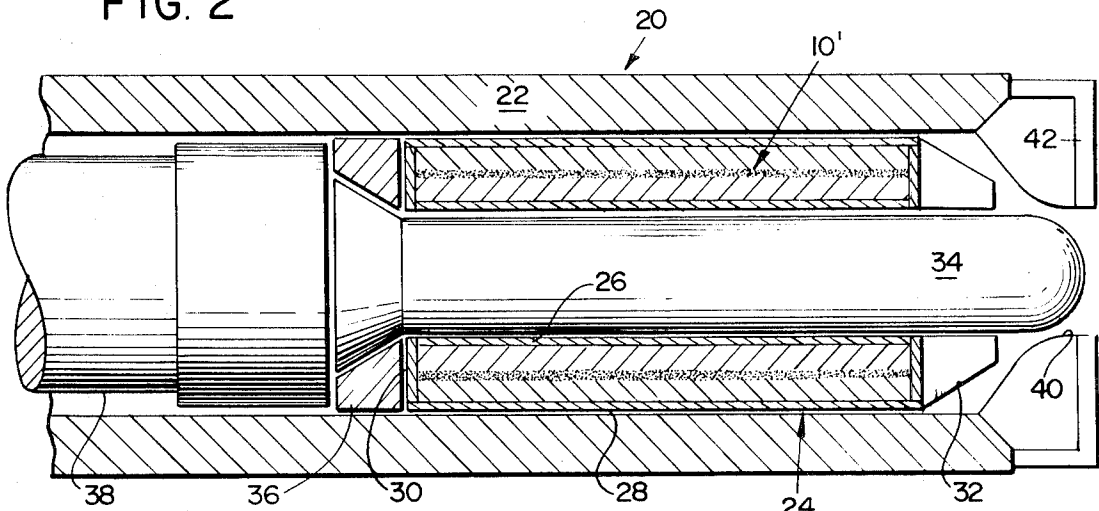


FIG. 3

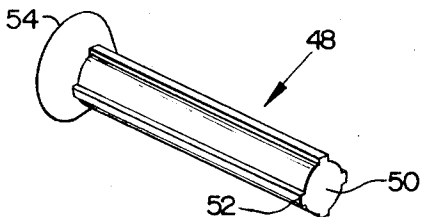


FIG. 4

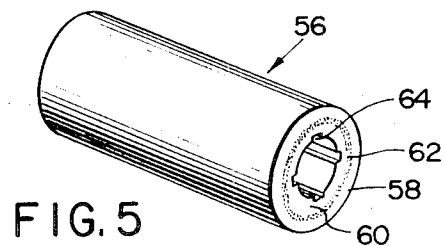


FIG. 5

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TUBULAR, SEAMLESS, DUAL-HARDNESS ARMOR PLATE

This application is a continuation-in-part of Ser. No. 719,386, filed Apr. 8, 1968, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to armor plate, and more particularly to tubular, dual-hardness armor plate. The armor plate is formed from two concentric shells, the outer shell being hard but brittle and the inner shell being soft but ductile.

2. Prior Art

In general, the defining characteristic of armor plate is its superior resistance to penetration by impact. In addition to its obvious use by the military for providing protection from ballistic projectiles, armor plate also finds advantageous use in many commercial applications. This is especially true of tubular armor plate, which forms the subject matter of the present invention. For example, it may be used as the housing for a hydraulic actuator in aircraft subject to small arms fire; it may be used in oil well drilling in the form of hollow pipes which must be protected against the sharp and frequent impact of drilling tools, or it may be used in a variety of other applications.

Previously, armor plate was formed from generally homogeneous materials such as the various steels which were subjected to one or more hardening treatments such as work hardening or dispersion strengthening, among others. The impact resistance of such materials was still much less than desired and frequently it was necessary to use exceptionally thick shells to provide the desired degree of resistance.

Recently, "dual-hardness" armor plate having a hard but brittle outer layer bonded to a tough but ductile inner or base layer has been utilized to provide improved impact resistance. In such materials, the hard outer layer presents a resistant surface to the impacting element and protects the underlying ductile layer from penetration while the ductile base layer provides support for the outer brittle layer and prevents its brittle fracture. Presently, dual-hardness armor plate is processed by roll bonding to each other a pair of flat plates, each plate having the desired characteristics. The resultant product is a flat plate of dual-hardness material which is then fabricated to form the desired end shape.

When tubular shapes are desired, it is necessary to weld or otherwise join the edges of the flat plate together after the plate has been rolled or otherwise fabricated into the desired shape. Several difficulties attend this method of fabrication:

1. Seams are formed at the joined edges. These seams present areas of potential weakness either at, or immediately adjacent, the seam itself.

2. Difficulties are sometimes encountered in forming a proper weld line between the edges which are to be joined together due to the fact that two different materials are present in the weld area. Often a compromise is required in selecting an appropriate welding composition since the optimum welding composition for one of the materials forming the armor plate may be totally inadequate for the other. Again, this creates a potential weakness in the bimetallic plate.

3. Structural shapes of relatively small diameter (e.g. of the order of 3 inches or less in inside diameter) are difficult to form by common techniques such as roll-forming. Further, such techniques are generally inadequate for precisely forming long tubes of small inside diameter because roll-forming equipment with small rolls generally lacks the requisite high capacity.

4. Cross sections other than cylindrical generally introduce excessive complexity into the forming process and substantially increase the cost of the finished product. Other techniques, e.g., powder forming, which are often applied when complex shapes are desired, are not readily available when dealing with dual-hardness materials.

BRIEF SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide a seamless, dual-hardness, tubular armor plate.

5 A further object of the invention is to provide a seamless, dual-hardness, tubular armor plate having a hollow central core of any desired shape.

Another object of the invention is to provide a seamless, dual-hardness, tubular armor plate of relatively small cross section.

10 Yet another object of the invention is to provide a method of making a seamless, dual-hardness, tubular armor plate.

Still another object of the invention is to provide a method of making a seamless, dual-hardness, tubular armor plate with a hollow core of desired shape and size in a single forming operation.

15 I have found that the problems previously encountered in forming dual-hardness, tubular armor plate may be largely eliminated by applying the known techniques of tubular coextrusion directly to the fabrication of the tubular armor plate. In accordance with the invention, I prepare inner and outer concentric shells of ductile and brittle material respectively and coextrude these shells in a known manner to bond them directly to each other. The resultant product is a seamless, hollow core structure in the form of a tube having a cross-sectional area which may range from fractions of an inch to tens of inches and whose cross-sectional shape may range from the simple to the complex without increase in the difficulty of the forming process. The tube possesses excellent impact resistance and is rapidly and economically manufactured.

20 The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the article possessing the features, properties, and the relation of elements, which are exemplified in the following detailed disclosure while the scope of the invention will be indicated in the claims.

25 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:

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a view in perspective of a seamless, dual-hardness, tubular armor plate formed in accordance with the invention, portions being broken away to show the internal structure of the tube wall;

FIG. 2 is a view in perspective of a pair of inner and outer shells snugly fitted to each other prior to extrusion;

50 FIG. 3 is a longitudinal section of the tubular assembly of FIG. 2 positioned within a protective canister in an extrusion press just prior to extrusion;

FIG. 4 is a view in perspective of a mandrel suitable for forming a particular cross-sectional shape; and

55 FIG. 5 is a view in perspective of a bimetallic tube formed with the mandrel of FIG. 4.

SPECIFIC DESCRIPTION OF THE INVENTION

60 FIG. 1 shows a unitary tube 10 having an inner shell 12 of a first material surrounded by an outer shell 14 of a second material. The shells 12 and 14 are bonded to each other along their lateral surfaces by means of an intermetallic layer 16 which is formed between the inner and outer shells during the extrusion process. The inner shell 12 is formed from a tough but ductile material such as a low carbon steel having a carbon content ranging from 0.2 to 0.4 percent by weight of carbon and a hardness on the Rockwell C scale of from 45 to 53. The outer shell is formed from a hard but brittle material such as an intermediate to high carbon steel having a carbon content of from 0.5 to 0.6 percent by weight and a hardness on Rockwell C scale of from 57 to 63. A preferred material for both the inner and outer shells is an alloy steel having a composition of from 0.7 to 1 weight percent Mn, from 0.2 to 0.35 weight percent Si, from 1 to 3.5 weight percent Ni, from 0.5 to

1.25 weight percent Cr, from 0.4 to 0.6 weight percent Mo, not more than 0.01 weight percent P, not less than 0.01 weight percent S, from 0.25 to 0.40 weight percent carbon in the case of the inner shell and from 0.5 to 0.6 percent carbon in the case of the outer shell, the balance substantially iron. The hard outer shell shatters the projectile upon impact while the ductile inner shell provides the toughness to prevent fracture of the outer shell. If sufficiently hard material is chosen for the outer shell, projectiles impacting on it will generally not cause significant damage. Other objects which may impact with lesser velocity than that for which the tube is designed will generally be deflected without shattering or breaking but also without substantially harming it. The ductile inner shell holds the outer shell material together and prevents it from fracturing on impact of an object.

FIG. 2 is a view in perspective, with portions broken away, of the structure of FIG. 1 before the inner and outer shells are joined to each other; this structure is designated 10' in FIG. 2. The inner shell 12 and outer shell 14 comprise separate tubular shells positioned coaxial with each other and snugly fitted together; they are separated by an annular gap 18 which is exaggerated in FIG. 2 to emphasize the fact that they comprise separate shells prior to their bonding to each other. In practice, this gap will be quite small (of the order of thousandths of an inch) and may indeed even be unobservable to the naked eye.

After the tubular shells 12 and 14 are assembled together, they are inserted into an extrusion canister and then placed into the container of an extrusion press for consolidation by extrusion. This is illustrated in FIG. 3 of the drawing which is a side cross-sectional view of an extrusion press 20 having a cylindrical container 22 for holding the extrusion canister 24. The canister 24 is cylindrical in shape and has inner and outer sidewalls 26 and 28, respectively, enclosing the inner and outer walls of the tube 10 and an annular end wall 30 welded onto the sidewalls for sealing off the canister. A frustoconical nose cone 32 is welded or otherwise attached to the forward face of the canister 24. A hollow central core extending through the canister and the nose cone is occupied by a mandrel 34. The mandrel is seated in a pressure disc 36 positioned behind the canister 24. A ram 38 is positioned behind the pressure disc 36 for axial movement in the container 22. The ram is driven longitudinally along the axis of the canister by a power source such as a hydraulic actuator (not shown).

In operation, the ram 38 forces the pressure disc 36 against the canister 24 and thereby forces the canister through the extrusion die 40. This reduces the cross section of the canister and its contents and causes the inner tube 12 to form a metallurgical (i.e. a diffusion) bond with the outer tube 14. The mandrel 34 is moved forwardly with the pressure disc 36 during the extrusion; once the nose cone 32 and canister 24 begin to extrude through the die 26, the mandrel is centered in the die by the resultant flow of metal through it. In consequence, a hollow central core in the resulting structure is formed.

The resulting unitary tube 10 contains no seams which would weaken it and thus does not suffer from the disadvantages previously discussed in connection with prior methods of producing tubular armor plate. Further, the tubular form is imparted to the structure simultaneously with the bonding of the inner and outer tubular shells to each other, thus eliminating the additional roll-forming and edge-joining steps which were previously required. The invention therefore produces an improved product in a more economical manner.

In performing the extrusion, the usual precautions should be observed. For example, the shells 12 and 14, which may themselves be formed by a prior extrusion, by drilling a hollow core in solid rod stock, or by other known methods, should be thoroughly cleaned prior to assembling them together; this ensures that mating surfaces are free of dirt and other contaminants which would prevent the formation of a good bond between the shells. Preferably, the materials to be bonded should each have a stiffness [defined as the factor K in the expression $P = K \ln R$, where P is the extrusion pressure and R is

the reduction in cross section resulting from the extrusion] which differs from each other by no more than 50 percent to ensure a good metallurgical bond. Other conditions such as the extrusion temperature, the choice of a lubricant, the extrusion speed, etc. are dependent on the particular materials being bonded and are selected in a known manner.

So far, I have described my invention in connection with the fabrication of tubes having cylindrical hollow cores extending through them. My invention is not so limited, however, and tubes having other than cylindrical hollow cores may be formed. For example, FIG. 4 shows a mandrel 48 having a solid core 50 of generally cylindrical shape on the periphery of which longitudinally extending fins 52 are positioned. The core and the fins terminate in a frustoconical section 54 which fits into the pressure disc 36 of FIG. 3. The mandrel 48 is utilized in conjunction with the tubular assembly 10' of FIG. 2 in exactly the same manner that the mandrel 34 is utilized in FIG. 3.

The resultant extruded product is shown in FIG. 5 as a tube 56 having an outer shell 58 bonded to an inner shell 60 by means of an intermetallic layer 62 corresponding to the intermetallic layer 16 of FIG. 1. Instead of the usual inner cylindrical hollow core, the tube 56 has a hollow core which is generally cylindrical in shape but modified by the presence of channels 64 extending longitudinally through the tube. It will be noted that this noncircular cross section is formed simultaneously with the formation of the bond between the two shells, thus obviating additional shaping steps previously required and thereby providing a simpler and more economical method of fabrication of the tubular armor plate. It will be appreciated that other and more complex central cores may, of course, also be formed if desired by choosing a suitable mandrel.

From the above, it will be seen that I have provided a tubular, seamless, dual-hardness armor plate. The armor plate has favorable impact resistance properties in comparison with armor plate formed by rolling flat plate and joining the edges of the flat plate together by means of welding or other joining techniques. The armor plate may have a cross section varying in magnitude from very small to very large dependent upon the ballistic protection required and the shape of its hollow central core may take any of a wide variety of shapes, from the simplest cylindrical shape to very complex shapes. These shapes may be formed in the same forming operation which bonds the initial shells of different materials to each other. This allows tubular armor plate of any desired cross section to be formed rapidly and economically while obtaining a product which provides excellent impact resistance.

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 carrying out the above method and in the article set forth 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. Tubular, seamless, dual-hardness armor for resistance to penetration by ballistic projectiles, said armor comprising a first seamless, continuous cylindrical shell of a tough but ductile metallic material having a hardness on the Rockwell C scale of from 45 to 53, said shell defining a hollow core, encased within a second seamless, continuous cylindrical shell of a hard but brittle metallic material having a hardness on the Rockwell C scale of from 57 to 63, said second shell surrounding said first shell and being joined thereto along lateral mating surfaces by a metallurgical bond whereby the brittle second shell is protected from fracture on impact with a projectile by said ductile first shell to which it is bonded.

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2. Tubular armor according to claim 1 in which said second shell has a diameter of less than 3 inches.

3. Tubular armor according to claim 1 in which said first shell comprises a hardenable carbon steel having a carbon content of from 0.2 to 0.4 percent by weight and in which said second shell has a carbon content of from 0.5 to 0.65 percent by weight.

4. Tubular armor according to claim 3 in which said first and second shells are formed from alloy steel having: from 0.7 to 1 weight percent Mn; from 0.2 to 0.35 weight percent Si; from 1 to 3.5 weight percent Ni; from 0.5 to 1.25 weight percent Cr; from 0.4 to 0.6 weight percent Mo; not more than 0.01 weight percent P; not more than 0.01 weight percent S.

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