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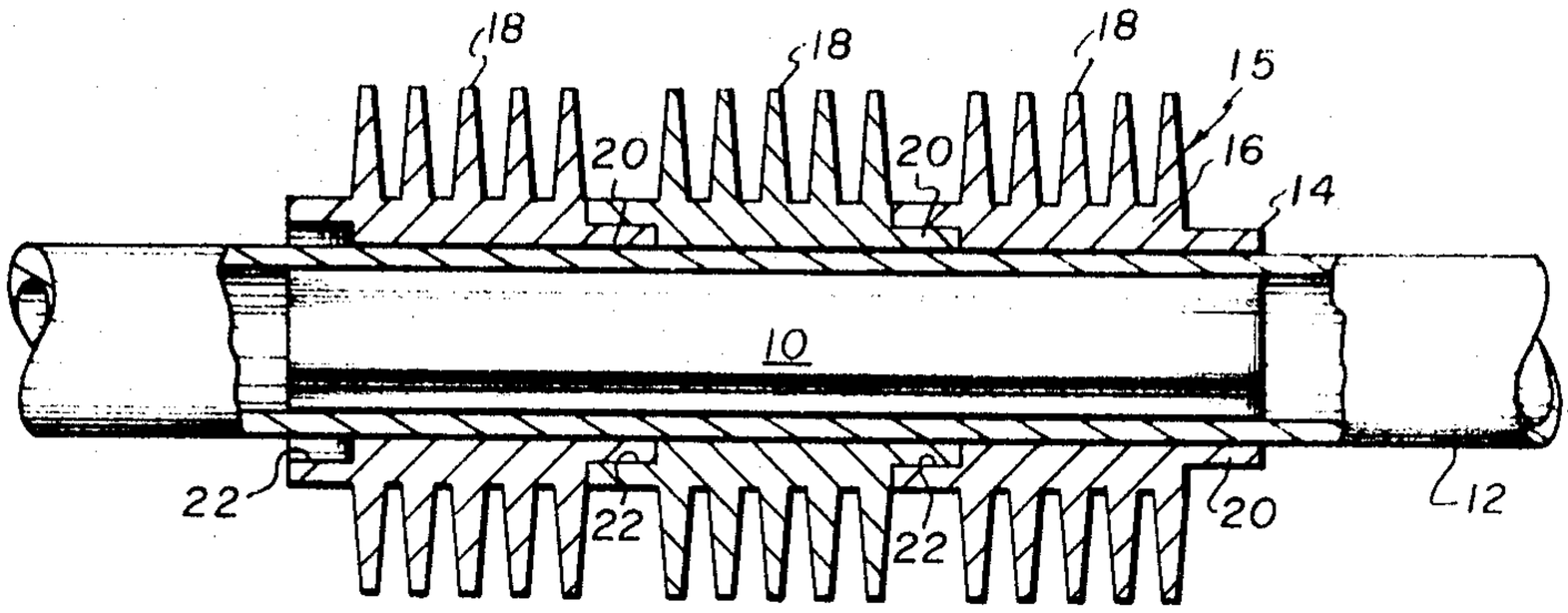
EXPLOSIVE FORMING OF INNER CYLINDERS INTO OUTER CYLINDERS

Filed Aug. 21, 1969

FIG. 1



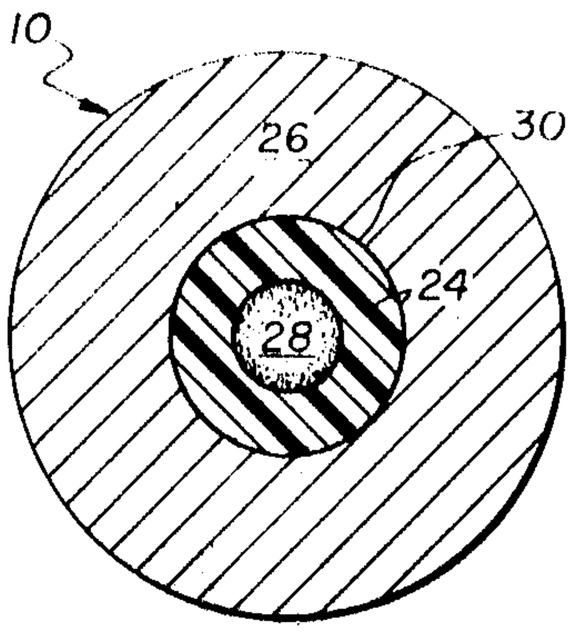


FIG. 2

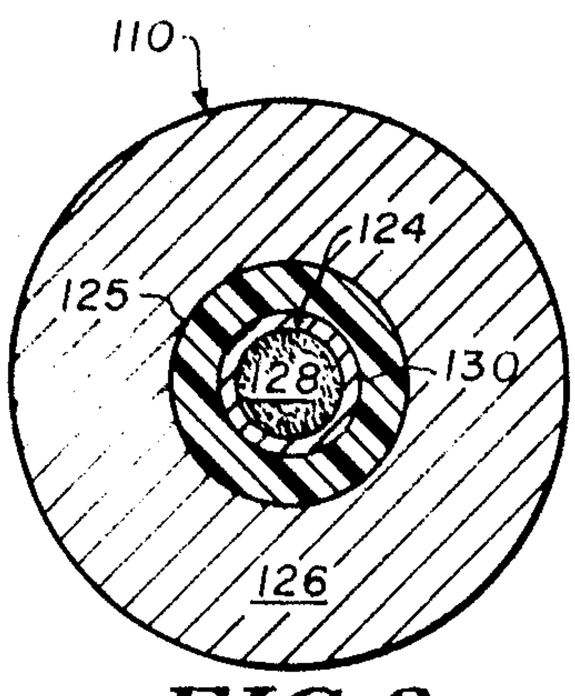


FIG. 3

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EXPLOSIVE FORMING OF INNER CYLINDERS INTO OUTER CYLINDERS

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ABSTRACT OF THE DISCLOSURE

Apparatus for expanding a hollow inner tube into a hollow outer tube in which an explosive forming insert is mounted in the inner tube. The insert includes a two-piece coaxially polyethylene cylinder surrounding the explosive charge.

BACKGROUND OF THE INVENTION

In the fabrication of heat exchangers of the type comprising an inner cylinder and a coaxially mounted outer cylinder it has been the usual practice to heat the outer cylinder for shrink-fitting onto the inner cylinder. This procedures does not result in a positive connection between the shrink-fitted cylinders.

In accordance with the present invention, explosive forming techniques have been utilized to provide an insert which can be coaxially positioned within the inner most cylinder. By using explosive forming techniques it is possible to achieve coining of the outer surface of the inner cylinder onto the inner surface of the outer cylinder. When coining occurs the abutting surfaces of the cylinders are brought into complete contact beyond the elastic limit of the material. Whereas, when only skrink-fitting procedures are utilized, it is not possible to obtain coining, since the surfaces cannot be brought into complete contact as the shrink-fitted materials remain within their elastic limit.

As a further feature of the invention, a multipart plastic insert of polyethylene is provided by forming the outer polyethylene section with a substantially greater cross-sectional wall thickness than that of the inner section, it is possible to reuse the outer section. This is possible since the outer section can withstand the detonation of the explosive charge without being permanently deformed.

SUMMARY OF THE INVENTION

In accordance with illustrative embodiments demonstrating features and advantages of the present invention there is provided an apparatus for expanding an inner cylinder into an outer cylinder comprising an insert coextensive with the inner cylinder. The insert includes an inner section formed with a central axial bore having a predetermined number of grains of explosive uniformly disposed along the axis of the insert, and an annular tubular force transmitting outer section between the inner section and the inside surface of the inner cylinder. The outer section has a substantially greater cross-sectional area than the inner section and the outer section and the inner section are formed from a thermoplastic hardenable resin of the class consisting of polyethylene, and resins having essentially the same flexibility, formability, resiliency, density and at least about as high a melting point as polyethylene.

BRIEF DESCRIPTION OF THE DRAWINGS

The above brief description, as well as further objects, features and advantages of the present invention will be more fully appreciated by reference to the following

detailed description of a presently preferred but nonetheless illustrative embodiments in accordance with the present invention, when taken in connection with the accompanying drawings wherein:

FIG. 1 is a sectional view of a portion of an inner cylinder coaxially mounted within an outer cylinder in which the explosive forming apparatus of the present invention is employed;

FIG. 2 is an enlarged sectional view of the explosive forming insert shown in FIG. 1 but removed from the inner cylinder; and

FIG. 3 is an enlarged sectional view similar to FIG. 2 but showing an insert having two separate outer sections.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, in accordance with the present invention there is provided an explosive expanding insert generally designated by the reference numeral **10** which is coextensively and coaxially positioned with respect to an inner cylinder **12**. The insert **10** is for explosively expanding the inner cylinder **12** into an outer cylinder generally designated **14** to form a tubular heat exchanger **15**. The outer cylinder **14** includes a plurality of gill rings **16**. It is preferable to form the gill rings **16** from cast iron such that each of the gill rings **16** is provided with a series of heat transmitting fins **18**. Each of the gill rings **16** are provided with a cylindrical boss **20** at one end and an annular socket **22** at the opposite end, in order that the gill rings **16** can be assembled in abutting relationship to form outer cylinder **14** which is coaxially mounted onto inner cylinder **14**.

For generating an explosive force, the insert **10** is formed with an external diameter for positioning within the inner cylinder **12** and with a length which is substantially coextensive with that of outer cylinder **14**.

In accordance with the embodiment shown in FIG. 2, the explosive forming insert **10** comprises an inner section **24** and an outer section **26**. The inner section **24** includes a central axial portion **28** which contains a predetermined number of grains of explosives, generally from 25 grains per foot to 100 grains per foot, which are uniformly disposed along the axis of the insert **10**, and a shell **30** of fiber or plastic material in which the explosive of axial portion **28** is embedded. The inner section **24** is marketed under the registered trademark "Primacord." It is preferable to fabricate the outer insert **26** from a force transmitting medium such as polyethylene or a thermoplastic hardenable resin having essentially the same properties of polyethylene, such as the flexibility, formability, resiliency, density, and at least as high a melting point. Suitable mediums other than polyethylene are polyvinyl acetals, polyvinyl butyrals, polystyrene, nylon, Teflon, polyester resins, Delrin, Lexon, polypropylene and Tygon. These materials have essentially the same flexibility, formability, resiliency, density, and at least about as high a melting point as polyethylene.

In FIG. 3 there is illustrated a further embodiment of the invention in which corresponding parts have been designated by the same reference numerals as part of a 100 series. In this form of the invention, a multiple layer insert **110** is provided. The insert **110** includes an inner section **124** which is coaxially positioned within an intermediate section **125**, which in turn is coaxially positioned in an outer section **126**. The inner section **124** includes an axial portion **128** which is encompassed by a thin outer shell **130**. The axial portion **128** contains a predetermined number of grains of explosive which are embedded in the shell **130** that is fabricated from a fiber or plastic mate-

rial, and the inner section **124** is generally marketed under the registered trademark "Primacord."

In the fabrication of the tubular heat exchanger **15**, the inner tube **12** is generally cold drawn with close tolerances, and the gill rings **16** are preferably cast in approximately six inch lengths with the inner portion of the gill rings **16** being broached. The gill rings **16** are then carefully heated and shrunk onto the inner tubes **12** in sequence. This results in an elastic compression of the inner tube **12** by the gill rings **16** as they cool and shrink. In this heat shrinking operation, it is difficult to obtain complete metal to metal contact between the outer surface of cylinder **12** and the inner diameter of gill ring **16**. When complete surface to surface contact is obtained, this is known as "coining." In order for coining to occur the two metallic surfaces are brought into contact such that the inner cylinder **12** is extended beyond its elastic limit, whereas in the shrink fitting operation, the inner cylinder **12** is not passed beyond its plasticity phase and there are sharp corners along the contacted surfaces between the gill rings **16** and the inner cylinder **12**, which result in discontinuities where there is lack of contact, and this serves as a barrier to good heat transfer between the inner cylinder **12** and the gill rings **16**.

In view of the difficulties attendant with the shrink-fitting step, after the inner cylinder **12** has been inserted in the gill ring **16** in the manner outlined above, the explosive expansion insert **10** or **110** is coaxially placed within the inner cylinder **12** in a position which is coextensive with the length of the gill ring **16**. The expansion inserts **10** and **110** can be detonated by an electrical type detonator which is well known in the art. By utilizing the explosive forming technique in accordance with the present invention, the explosive force generated through the wall thickness of inner cylinder **12** will follow the surface contour for small and sharp variations along the inner bore of the gill ring **16**, such that the portion of the inner cylinder **12** which contacts the gill ring **16** passes beyond the elastic limit.

A latitude of modification, change and substitution is intended in the foregoing disclosure and in some instances some features of the invention will be employed without a corresponding use of other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the spirit and scope of the invention herein.

What is claimed is:

1. An insert for explosively expanding an inner cylinder into an outer cylinder that includes a plurality of individual gill rings of a frangible material and said gill rings formed with annular sockets at one end and cylindrical bosses at the other end, such that said gill rings can be positioned in abutting relation along said inner cylinder with said cylindrical boss received in the annular socket of adjacent gill rings and said outer cylinder being coextensively and coaxially positioned with respect to said inner cylinder, and said insert comprising

an outer tubular section coaxially positioned in said inner cylinder,

an inner tubular section coaxially positioned in said outer tubular section,

said inner tubular section including an explosive section formed with a central bore having a predetermined number of grains of explosive uniformly disposed along said bore and an inner shell which coaxially surrounds said explosive section,

said outer tubular section and said inner shell being formed from a thermoplastic hardenable resin of the class consisting of polyethylene, and resins having essentially the same flexibility, formability, resiliency, density and at least about as high a melting point as polyethylene, and

said outer tubular section having a substantially greater cross sectional area than said inner shell.

2. An insert for explosively expanding an inner cylinder into an outer cylinder that includes a plurality of individual gill rings of a frangible material and said gill rings formed with annular sockets at one end and cylindrical bosses at the other end, such that said gill rings can be positioned in abutting relation along said inner cylinder with said cylindrical boss received in the annular socket of adjacent gill rings and said outer cylinder being coextensively and coaxially positioned with respect to said inner cylinder, and said insert comprising

an outer tubular section coaxially positioned in said inner cylinder,

an inner tubular section coaxially positioned in said outer tubular section,

said inner tubular section including an explosive section formed with a central bore having a predetermined number of grains of explosive uniformly disposed along said bore and an inner shell which coaxially surrounds said explosive section,

an intermediate tubular section coaxially positioned between said inner tubular section and said outer tubular section,

said outer tubular section, said intermediate tubular section, and said inner shell being formed from a thermoplastic hardenable resin of the class consisting of polyethylene, and resins having essentially the same flexibility, formability, resiliency, density and at least about as high a melting point as polyethylene, and

said outer tubular section having a substantially greater cross sectional area than said intermediate tubular section.

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U.S. Cl. X.R.

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