May 7, 1957 D. J. REED 2,791,241

FIBER REINFORCED TUBULAR ARTICLE

Filed July 6, 1954

FIG. 1.

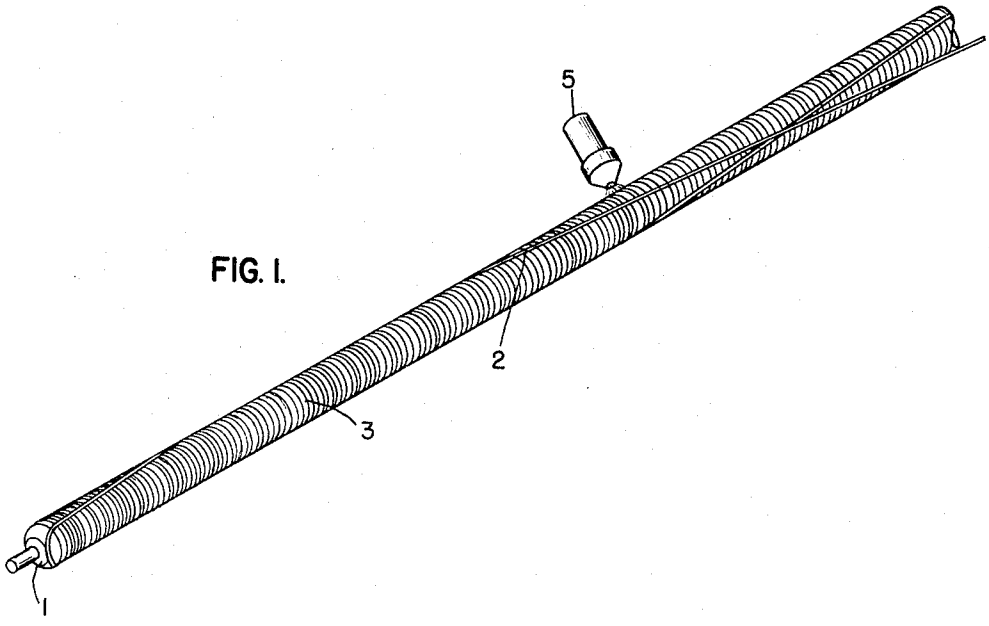


FIG. 2.

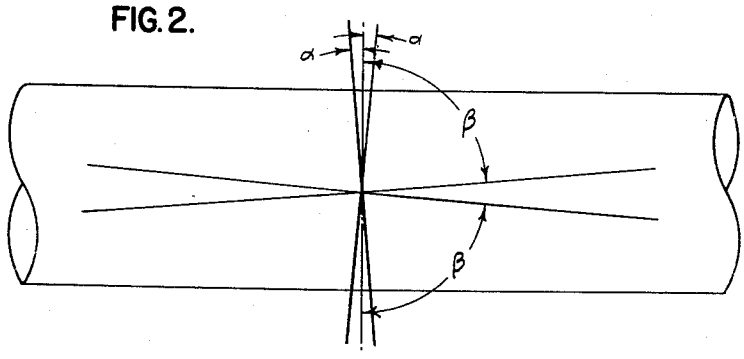
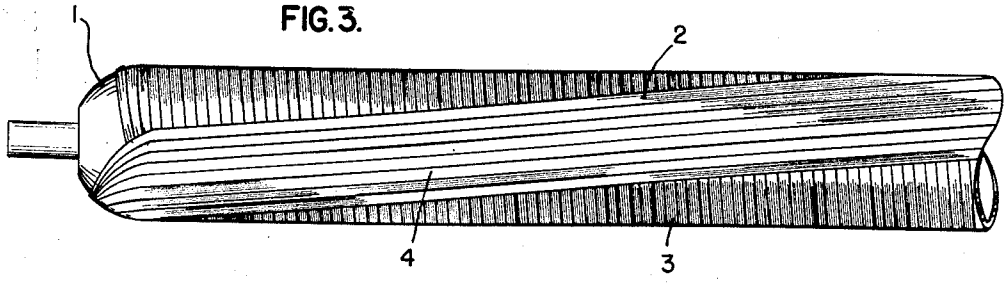


FIG. 3.



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United States Patent Office

2,791,241

Patented May 7, 1957

2,791,241

FIBER REINFORCED TUBULAR ARTICLE

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Application July 6, 1954, Serial No. 441,493

3 Claims. (Cl. 138—76)

This invention relates to tubular articles and more particularly to fibrous reinforced resin pipe.

The stresses in a pipe due to internal pressure can be resolved into longitudinal and circumferential stresses, and it has been determined that for a given internal pressure the circumferential stress is approximately twice that of the longitudinal stress in a pipe with free ends.

To fabricate a fiber-wound pipe having a circumferential strength twice that of the longitudinal strength, the fibers are usually wound in a double helical pattern with a helix angle of about 35.4°. However, under internal stress conditions with a 35.4° helix angle of winding, there is some shifting or movement of fibers which is undesirable. The internal pressure tends to shift the helical windings of one layer with respect to those of the adjacent layer having the reversed helix angle. This shifting movement causes shear stresses to be set up within the pipe and these shear stresses crack or craze the resin with the result that leaks frequently occur in the pipe.

According to the present invention the pipe is wound so that the pattern of winding more nearly coincides with the major and minor axes of stress. The invention is directed to a pipe having two separate patterns of winding, one pattern of winding having a helix angle of from 2° to 10° and the other pattern having a helix angle of about 80° to 88°. In addition, the number of fibers laid up with a 2° to 10° helix angle are approximately twice that in number of the fibers wound with a helix angle of 80° to 88°.

With this novel pattern of winding the fibers can more effectively resist internal stresses and there will be a minimum of movement of shifting between the layers of fibers, so that the shear stresses present in the conventionally wound pipe will be virtually eliminated.

The drawing furnished herewith illustrates the best mode of carrying out the invention as presently contemplated and set forth hereinafter.

In the drawing:

Figure 1 is a perspective view of a pipe being wound in the manner of the present invention;

Fig. 2 is a fragmentary schematic representation showing the angles of winding; and

Fig. 3 is a fragmentary side elevation of a pipe partially wound in the manner of the present invention.

Referring to the drawing, there is shown a generally cylindrical mandrel **1** which is wound with a fibrous reinforcing strand or roving **2** to form a tubular article or pipe.

The mandrel is rotated and either the mandrel can be advanced longitudinally or the winding head, not shown, which carries the roving **2** can be moved longitudinally with respect to the mandrel to provide relative movement between the mandrel and the roving and thereby permit the roving to be wound in a generally helical pattern on the mandrel.

The roving consists of long reinforcing fibers of glass, asbestos, or animal or synthetic material. The roving

is wound on the mandrel **1** in a generally helical pattern with a helix angle of from 2° to 10° to form a cylindrical layer **3** of the pipe. As shown in Fig. 2, the helix angle is taken to be the angle α between a transverse plane extending normal to the axis of the pipe and a tangent to the fiber at the point of intersection with the plane.

To obtain the layer **3** with a helix angle of from 2° to 10° it may be necessary that the roving convolutions overlap each other, depending on the width of the roving and the diameter of the pipe. The minimum helix angle that can be employed with the longitudinal edges of the roving disposed in an abutting relation is determined by the following formula:

$$\text{Tan}^{-1}=\frac{W}{\pi D}$$

where the Tan^{-1} is the helix angle, W is the width of the roving and D is the diameter of the pipe. From this formula it can be seen that when using a substantially wide roving, in the neighborhood of from 3 to 4 inches, and a small diameter mandrel of about 2 inches, the minimum helix angle that can be obtained with the edges of the roving abutting would be 40° to 50°. Thus to carry out the present invention, when using materials with a width substantially as specified, it is necessary that the convolutions overlap each other so that the fibers are disposed at a helix angle of from 2° to 10°.

A second layer of helical windings, indicated by **4**, is wound, with the fibers at a helix angle β of from 80° to 88°, as a superimposed layer on the original layer **3**. The layer **4** is produced by winding a strand or roving of long reinforcing fibers in a manner similar to that of the windings in layer **3**.

The wall thickness of the pipe is built up by alternating the layers of windings having a helix angle of 2° to 10° and a helix angle of 80° to 88° until the desired wall thickness is obtained. The helix angle of the windings of each of the layers **3** is alternately reversed, and similarly, the helix angle of the windings of each of the layers **4** is alternately reversed to balance the stresses. The thickness of the wall depends on the ultimate use of the pipe and the strength requirement for that use. Ordinarily a pipe may be fabricated with from 10 to 20 layers such as those indicated by **3** and **4**.

To obtain the maximum strength in the pipe for a given wall thickness the number of fibers wound at a helix angle of 2° to 10° should be approximately twice that of the fibers wound at a helix angle of 80° to 88°. With this pattern of winding, the fibers generally coincide with the major and minor axes of stress so that the pipe will more adequately resist the internal stress with a minimum amount of movement or shifting of the fibers.

As shown in Figure 1, the fibers in the layers **3** and **4** are sprayed with a bonding material, such as a liquid unpolymerized thermosetting resin, by means of nozzle **5**. The resin may be applied to the roving before winding or after the windings have been laid up on the mandrel **1**. It is contemplated that any method of resin application can be employed with the present invention. More specifically, the resin can be applied by dripping or spraying the same on the wound pipe, rotating the lower portion of the mandrel through a resin bath, passing the roving through a resin bath prior to winding or any other desired method.

The present invention provides a novel pattern of winding for a fiber reinforced resin pipe which increases the strength of the pipe and minimizes the crazing occurring in the resin due to the shear stresses set up by the shifting of the fibers by internal pressure.

The resin used to coat the winding material may take

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the form of a thermosetting polyester resin such as a polyester resin in which at least one of the reactants contains an unsaturated double bond in an aliphatic group. For example, the unsaturated bond may be in the polybasic acid component such as when maleic acid or anhydride is reacted with a polyhydric alcohol such as glycerol, ethylene glycol, diethylene glycol, propylene glycol, sorbitol, mannitol, pentaerythritol, polyethylene glycol and the like. In addition thermosetting resins of the diallylphthalate, epoxide, furane and vinyl types may also be employed as the resin coating for the fibrous material.

Various modes of carrying out the invention are contemplated as within the scope of the following claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention.

I claim:

1. A fiber reinforced resin pipe, comprising a series of long reinforcing fibers wound helically at a helix angle of from 2° to 10°, a second series of long reinforcing fibers wound helically with a helix angle of from 80° to 88° and superimposed on said first series, the number of fibers of said first series being approximately twice the number of fibers of said second series to generally coincide wtih the major and minor axes of stress in the pipe, and a thermo-setting binding material securing said fibers together to form an integral pipe.

2. A method of making a fiber reinforced tubular article with an integral, generally curved head portion comprising the steps of winding a fibrous strand of reinforcing material in a series of convolutions having a helix angle of 2° to 10° to form a generally cylindrical layer of the article, winding a fibrous strand of reinforcing material on said layer in a second series of convolutions having a helix angle of 80° to 88° to form a second layer of the article superimposed on said first layer, reversing the pitch of each of said second convolutions at the ends of said first layer by passing each of said second convolutions through a path having a contour of a portion of a sphere to form a generally spherical head portion integral with said second layer, and bonding the fibrous strands together to form the tubular article.

3. A fiber reinforced resin pipe, comprising a plurality of layers of long reinforcing fibers wound helically with said fibers disposed at an angle of about 2° to 10° to a transverse plane extending normal to the axis of the pipe, additional layers of long reinforcing fibers disposed alternately in superimposed relation with said first named layers and with the fibers of said additional layers disposed at an angle of from about 80° to 88° to said plane and extending in continuous loops from one end of the pipe to the other, and a cured resin bonding said fibers together to form an integral pipe having increased strength and increased resistance to shear stresses set up in the pipe due to internal pressure.

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