Dec. 20, 1966 J. R. HILL 3,292,408

METHOD OF FORMING INTERNALLY RIBBED TUBES

Filed June 22, 1964

FIG. 1

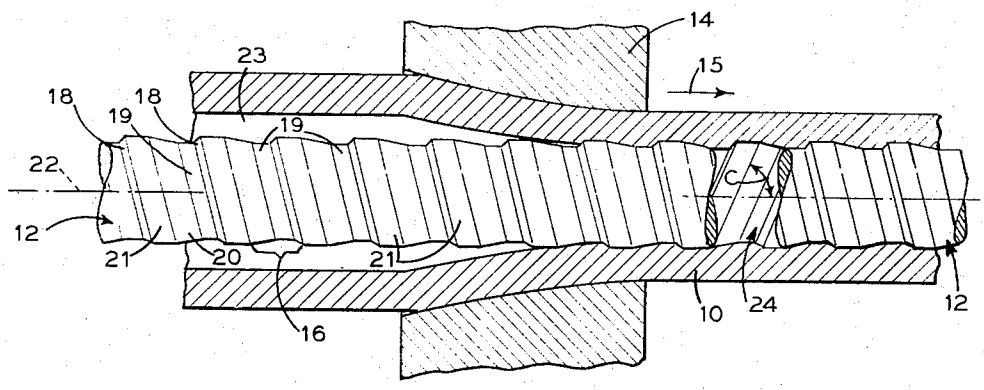


FIG. 2

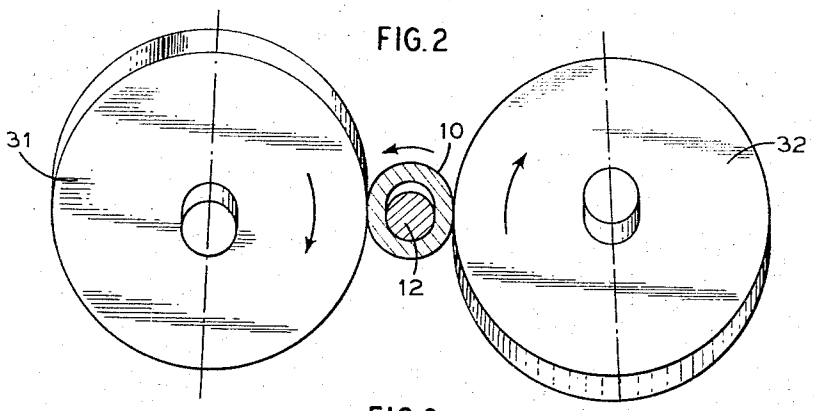


FIG. 3

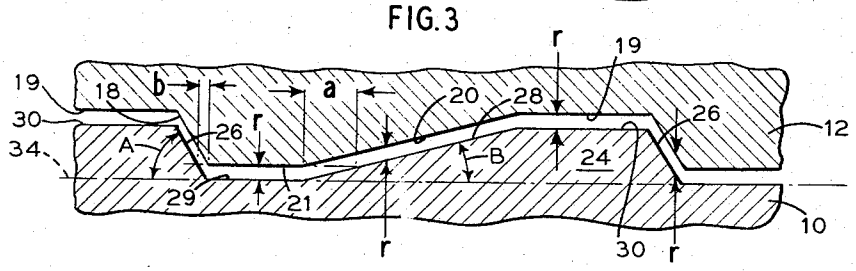
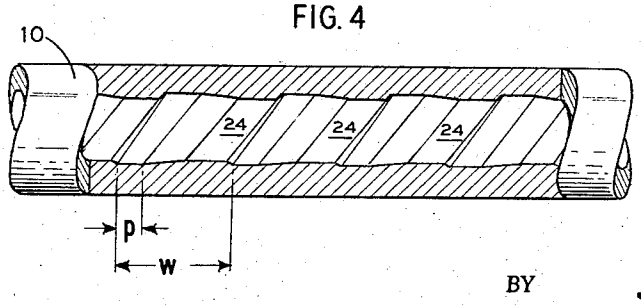


FIG. 4



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METHOD OF FORMING INTERNALLY RIBBED TUBES

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This invention relates to a method for forming internally ribbed tubes, especially internally ribbed tubes which promote nucleate boiling according to the theory described in U.S. Patent 3,088,494 of P. H. Koch et al., entitled "Ribbed Vapor Generating Tubes," issued May 7, 1963 and assigned to The Babcock & Wilcox Company.

It previously has been proposed to machine or cut internal helical grooves in a tube to define internal helical ribs. However, the present invention has to do with forming such internal helical ribbing by inserting a helically grooved forming rod or mandrel in a smooth bore tube and then drawing the assembly through a die so that metal of the tube wall will flow into, and take the obverse shape of, the grooves of the froming rod. After formation of the ribs throughout the length of the tube by this method, there is the problem of overcoming frictional resistance to removal of the forming rod from within the tube, for which this invention provides a solution. This difficulty would not be present if the method were employed for forming internal rib-like formations in very short hollow tubular members because in that case the frictional resistance to unthreading the rib-forming rod to remove it from the tube is of little or no consequence.

The present invention proposes to facilitate the removal of the rod by increasing the radial clearance between the ribbed tube and the forming rod. This is accomplished by a reeling operation performed subsequent to forming of the ribs and involves rolling the tube in compression between a pair of spaced rollers which have their axes of rotation extending in the same general direction as the longitudinal axis of the tube. A reeling operation is known to produce an increase in the inside diameter of a tube without substantially changing the wall thickness of the tube, with the result that there is a co-incidental longitudinal contraction or shortening of the tube. An increase in inside diameter of the tube provides the radial clearance necessary for easy rod removal, but the longitudinal contraction, which is of no consequence in the reeling of smooth bore tubes, in ribbed tubing manufacture does produce an interference fit in the direction of longitudinal axis of the tube, resulting in binding between the formed ribs and the forming ribs if the ribs are sized and symmetrically shaped as disclosed in the aforementioned Koch et al. patent.

Accordingly, the present invention proposes, still further, that the forming rod have a helical groove of asymmetrical profile, so that the profile of the internal tube rib formed thereby will be likewise asymmetrical, with one land being steep and the other land being of more shallow or lesser slope relative to the longitudinal axis of the tube. The shallow sloping land is purposely provided to provide both axial and radial clearances between the tube rib and the forming rib as a result of the tube reeling operation, the clearance being sufficient to permit easy withdrawal of the grooved rod or mandrel.

The present invention therefore provides a method of die forming, as a manufactured product, an internally ribbed tube, the contour of the rib being such as to overcome the problem of separating a forming rod from the tube notwithstanding the interlocking nature of the rib formations.

Various other objects, features and advantages of the invention will appear more fully from the detailed description which follows, taken in connection with the accompanying drawings forming a part of the application and in which:

FIG. 1 is a side view, partly in section, of a helically-grooved forming rod carrying a tubeblank being drawn through a die, with a portion of the rod being broken away to show the helical ribs;

FIG. 2 is an end view of a tube compressed between a pair of rollers during the reeling step in the method of the present invention;

FIG. 3 is an enlarged fragmentary view, viewing in profile the mating groove and rib surfaces of the drawn tube and its forming rod in exaggerated radially separated relation; and

FIG. 4 is a longitudinal sectional view of a finished tube after drawing, reeling and sinking operations, shown having internal ribbing produced according to the method of the present invention.

In the drawing, the present invention is shown applied to a method of forming internal ribs in an elongated tube **10** especially a tube upwards of twenty feet in length. This method involves first inserting a helically grooved mandrel or rod **12** into the smooth bore of the tube **10** and then drawing or otherwise forcing the assembly through a die **14** in the direction indicated by the arrow **15** in FIG. 1. As shown in FIG. 1, the internal surface of the tube **10** assumes the counterpart or obverse shape of the external surface of the rod **12** as a result of having a portion of the tube metal deformed by pressing or flowing it into the helical groove **16** of the rod **12** during the passage through the die **14**.

The contour of groove **16** in rod **12** is characterized by the oppositely sloping sides **18** and **20** which are adjacent a root surface **19** (see FIG. 3). According to the invention, the sides **18** and **20** are of steep slope and gentle or lesser slope, respectively, with respect to the longitudinal axis **22** of the rod, when the groove **16** is viewed in profile. Between neighboring helical turns of the groove **16** there is the crest or land surface **21** also of helical form and disposed about the longitudinal axis **22** of the rod **12**. It is preferred that the steep side **18** of each groove **16** be drawn through the die **14** after the gently sloping side **20** thereof, as shown, to minimize frictional forces and consequent stress on the forming rod **12**; but the invention can be practiced by drawing either end of rod **12** through the die **14** first.

As has been stated, by the method of the present invention the internal surface of the tube **10** has impressed into it a helical grooved rib **24** which is the counterpart of the groove **16**; and, thus, the internal helical rib **24** within tube **10** has a steeply sloping side **26** and a gently sloping side **28**, respectively, corresponding in shape and slope to the sides **18** and **20** of the surface of groove **16** and with the land **29** between the sloping sides corresponding to the crest surface **21** on rod **12**. Also, the helical face or land **30** of the rib **24** corresponds to the root **19** of the groove **16**. As shown in FIG. 1, the rib **24** makes an angle C with the longitudinal axis of the tube **10**, with angle C being taken between a line tangent to the helical land **30** and axis **22**.

After the tube **10** has been drawn through the die **14**, it is in such tight engagement with its forming rod **12** that they can only be separated by adjusting the clearance between them sufficient to permit disengagement, and this is the principal concern of the present invention.

According to the present invention, it has been found that the formation of a helical rib **24** with one gently sloping side **28** and one steeply sloping side **26**, followed by a reeling operation, to be explained hereinafter, pro-

duces the requisite axial and radial clearances to permit separation of the tube **10** from the rod **12**.

The reeling apparatus includes a pair of spaced rolls **31** and **32**, shown in FIG. 2, which are suitably driven so as to rotate in the same direction about their respective axes, the axes extending in the same general direction as the longitudinal axis of the tube **10** which is passed therethrough. However, the axes of the rolls are slightly inclined in vertical planes, about 10° to 20°, to the horizontal, but in opposite directions, so as to impart a longitudinal force component to the tube which urges it through the restricted space between the rolls. The axes of the rolls **31** and **32** are also angularly inclined in a horizontal plane so as to converge in the direction of tube feed and travel in order to more readily admit and securely grip the tube between them.

During reeling, the rolls **31** and **32** compress portions of the tube wall against the rod **12**. This operation increases the clearance between the rod **12** and the tube **10** without appreciably affecting the cross-sectional area of the tube; and, as a result, the tube undergoes a longitudinal contraction which tends to produce an undesirable decrease in axial clearance between interlocking rib formations of the tube and the rod. As will be explained, the profile shape of the surface of the groove **16** in the rod **12** is selected, according to the invention, so that an increase in radial clearance effected by the reeling operation will be accompanied by an increase in axial clearance between interlocking helical formations, despite the longitudinal contraction of the tube.

Referring now to FIG. 3, fragments of tube **10** and rod **12** are shown in profile with exaggerated clearance between them in order to define more clearly both their angular relationship with the longitudinal axis and the profile clearances between their mating surfaces. The mating surfaces are viewed at an angle C to the longitudinal axis of the tube **10**, the tube **10** and rod **12** being spaced apart the distance *r* measured in a radial direction, and with *r* normal to a reference plane **34** which is parallel to a plane passing through the longitudinal axis **22** of rod **12**. In profile, the groove side **20** of groove **16** and rib side **28** of tube **10** are spaced apart the distance *a* measured along a line parallel to plane **34**, and the groove side **18** of groove **16** and rib side **26** of tube **10** are spaced apart the distance *b* measured along a line parallel to plane **34**. The mutually facing surfaces **18** and **26** make a steep profile angle A with reference plane **34**; and the mutually facing surfaces **20** and **28** make a gently sloping profile angle B with reference plane **34**. Thus the *a* and *b* relationships may be defined:

$$a=\frac{r}{\tan B} \qquad b=\frac{r}{\tan A}$$

It can be seen from the above, and also by inspection of FIG. 3, that in order to overcome the longitudinal contraction which inherently results from the reeling operation and causes binding, it is necessary to make angles A and B as small as possible. More specifically, when angle B for example is less than 45°, profile clearance distance *a* gains more rapidly than radial clearance *r* as a result of reeling. But in order for the finished tube to have the requisite ratio of rib face width *w* to pitch *p* (see FIG. 4) in the preferred range to promote nucleate boiling in accordance with the cited Koch et al. patent, it can be seen that only the remaining tube length as determined by the expression $(p-w)$ per helical turn is available for the purpose of forming the sloping sides **26** and **28** in accordance with the present invention. Limited thus, and also by considerations of mechanical strength, it is preferred that angle A be in the range of between 60° and 90° and that angle B be in the range of between 5° and 10°.

The foregoing was applied in the manufacture of ribbed tubing from a tube blank having an outside diameter of 1.375" and a wall thickness of .305", an angle A of 60°, and an angle B of 5°20'44" in order to obtain satisfactory results.

With a helical rib **24** made with one steep side **26** and one gently sloping side **28** in accordance with the foregoing, the reeling operation effectively provides sufficient clearance to overcome the phenomena of longitudinal contraction encountered as a result of the reeling operation. It its therefore now possible to remove the forming rod **12** from the tube **10** by a simple unthreading action.

After removal of the forming rod **12**, it is preferred that the internally ribbed tube **10** be drawn through a second die (not shown) in order to reduce the tube **10** to the desired or requisite outside diameter; and this second drawing operation is termed a sinking operation which produces a finished tube **10** as shown in FIG. 4. In the above-mentioned example, the sinking operation provided the finished tube with an outside diameter of .875" and a wall thickness of .237".

Although the best method of practicing the invention has been disclosed herein, it will be obvious to those skilled in the art that it is not so limited, but it is susceptible of various changes and modifications without departing from the spirit thereof as covered by the claims.

What is claimed is:

1. The method of forming internal helical ribbing in an elongated tube including the steps of: forming an internal helical groove of asymmetrical profile in said tube, with one side of the surface of said groove making an angle in profile of in the range of between 5° and 10° to the longitudinal axis of the tube by placing the tube over a forming rod having on its surface the converse of the configuration to be imparted to the tube and then drawing the rod carrying the tube through a die to thereby cause the internal surface of the tube to assume the shape of the rod surface, rolling the wall of said tube against said rod to thereby increase the clearance between said rod and said tube, and rotating the rod relative to the tube to remove said rod from the tube.

2. The method of forming internal helical ribbing in an elongated tube comprising the steps of: forming in said tube an internal helical groove of asymmetrical profile defined at least partly by oppositely facing sides, with the profile of one of said sides making an angle in the range of between 5° and 10° with a plane containing the longitudinal axis of said tube by placing the tube over a forming rod having on its surface the converse of the configuration to be imparted to the internal surface of the tube and then drawing said tube and said rod through a die to thereby cause the internal surface of said tube to assume the external shape of said rod and thus form said helical groove internally of said tube, rolling the tube containing said rod to expand said tube in radial direction, and removing the rod from the tube by rotating the rod relative to the tube.

3. The method of forming internal helical ribbing in an elongated tube comprising the steps of: forming in said tube an internal helical groove defined at least partly by sides facing in generally opposite directions, the profile of one side making an angle of greater than 45° with a plane containing the longitudinal axis of said tube and the profile of the other side making an angle of between 5° and 10° with said plane, by inserting in said tube a forming rod having on its surface the converse of the configuration to be imparted to the tube, and drawing the rod carrying the tube through a die to thereby cause the internal surface of said tube to assume the shape of the external surface of said rod, compressing wall portions of said tube between said rod and each of a spaced pair of rollers to expand said tube in radial direction, and removing the rod from the tube by rotating the rod relative to the tube.

4. The method of forming internal helical ribbing in elongated tubing and the like comprising the steps of: providing a tube having a uniform cross section and a smooth bore, forming in said tube an internal helical

groove formed therein for at least the length of the ribbing to be formed in said tube, and wherein one side of said groove in profile is at an angle in the range of between 60° and 90° with a plane containing the longitudinal axis of said tube, and the other side of which is at an angle in the range of between 5° and 10° with said plane, by inserting in said tube a mandrel having on its surface the converse of the configuration to be imparted to the tube, drawing said tube with said mandrel therein through a die so as to press the internal surface portions of said tube into the surface of said mandrel to thereby form a helical rib internally of said tube, compressing wall portions of said tube between said mandrel and a plurality of spaced rollers to increase the inside diameter of said tube, and removing the mandrel from the tube by rotating the mandrel relative to the tube.

5. The method according to claim 4 including the additional step of drawing the ribbed tube through a die to reduce its outside diameter.

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