This invention relates to methods of bending and sizing tubes and has for an object the production of sized tube bends with minimum change in wall thickness as between the tube blank and the final product.

In the past, elbows and bends have been formed by heating the tube blank and forcing it through dies and over a mandrel. Cold-bending of elbows has been accomplished by filling the tube blanks with liquid, wood's metal or sand prior to the bending thereof.

In view of the present invention, it is an object of the present invention to provide cold-form open-ended tube blanks with a tube-filling material which is not a liquid but which during the bending operation has the characteristics of a liquid and which does not require liquid-tight seals.

In carrying out the present invention in one form thereof, there is provided a die cavity of a diameter corresponding with the outside diameter of the tube blank and having a shape corresponding with the desired angle or angles of curvature of the final product. Each open-ended tube blank has been inserted therein a mandrel of a rubber-like material which under pressure exhibits a fluid characteristic. It has been found that many synthetic plastic materials, including natural rubber, exhibit the characteristics of a liquid upon application thereto of a high pressure. By employing a rubber-like material within the tube blank, liquid-tight seals at the respective ends of the tube blank need not be used.

Further, in accordance with the invention, each tube blank while being forced through the shaped die cavity has applied to the rubber-like mandrel a high pressure which causes the mandrel material to exhibit the characteristics of a fluid. The result is that the rubber-like material obeys Pascal's law for fluids and in particular for liquids. The high pressure acts on the interior of each tube blank in an outward direction to maintain the wall of the tube blank against the shaping surfaces of the die. To minimize friction during the movement of the tube blank through the die cavity, the shaping surface of the cavity is made of a metal differing from that of the tube blank. The particular metal will be selected on the basis of a sufficient hardness relative to that of the tube blank and on the basis of the lack of any tendency of the metal of the tube blank to be seized or to give rise to galling. After the tube blank has been moved through the forming die to form a tube bend, the pressure on the rubber-like filler material is increased to press the walls of the tube bend outwardly against the forming surfaces of the die to size the tube bend. This forming and sizing are accomplished in one die and by the same apparatus.

For a more detailed description of the invention and for further objects and advantages thereof, reference is to be had to the following description taken in conjunction with the accompanying drawings, in which:

Figs. 1 and 2 diagrammatically illustrate the method and one form of apparatus for practicing the invention; Fig. 3 is an elevation of the forming dies in the open position; Fig. 4 and 5 are respectively side elevation and sectional views of the flexible linkage; Fig. 6 is an exploded perspective view of a link unit of the flexible linkage; and Fig. 7 is a fractional side elevation of a modification of the flexible linkage.

Referring to Fig. 1, a tube blank 10 is shown inserted within the entrance portion of a die cavity formed by a pair of dies. Within the tube blank 10 is a rubber-like mandrel 12 of a material which, when subjected to high pressures, exhibits fluid characteristics. It may be a solid rubber cylinder, either of natural or synthetic rubber, or it may be made of many synthetic plastic materials, some of which will later be mentioned.

The lower end of the tube blank 10 is closed by a floating piston 13 which, it will be observed, closely fits within the lower end of the tube blank 10. The piston 13 may have a slight taper to insure entry into the tube blank or as shown, Figs. 1, 2, 4 and 5, it may have an end portion 13b of reduced diameter with a shoulder 13c, which when engaging the leading end of the tube blank limits the extent of movement of end portion 13b against the rubber-like mandrel 12.

Though not necessary for natural or synthetic rubber, the floating piston 13 may be provided with an annular recess for materials of lower viscosity than rubber. In this recess is located a ring or washer 13a forming an additional seal for the material forming the mandrel 12. Thus, the reduced end of floating piston 13 has a diameter to provide clearance with the usual variations in the internal diameter of successive tube blanks.

Pressure is applied to the floating piston 13 by the end of a ram 14 by way of a flexible linkage 15 comprising a plurality of pressure elements flexed together at their midportions and of diameter so that the linkage can readily traverse the arcuate shaping surface section of the die element as later to be described in detail.

At the upper end of the tube blank, Figs. 1 and 2, there is located at the end of a ram 16 a pressure-employing member 17 which has a shoulder portion 17a engaging the end of the tube blank 10 and a portion of reduced cross section nesting within the tube blank.

The tube blank is formed or bent into the desired shape by simultaneous application of pressure by the rams 14 and 16. With the ram 16 fully retracted, Fig. 1, and the four-way valve 30 in port-closing position, i.e. valve 30 rotated about 45° from the position shown in Fig. 1, the pump unit 18 is energized for flow of hydraulic fluid through a relief valve 20, a check valve 21, and by way of line 22 into the right-hand end of the cylinder 19 associated with ram 14. Fluid pressure is developed against the piston 23 which moves to the left in cylinder 19 to build up pressure on the rubber-like mandrel 12.

The pressure build-up occurs by reason of the movement of the reduced end portion 13b against the rubber-like mandrel 12. As it is compressed, it develops outward forces which act the same as would pressures developed by a liquid under pressure. The magnitude of the pressures will depend upon the movement of the end portion 13b and the pressure applied by the piston 23 to that end portion. To pressurize the rubber-like mandrel 12, required movement is small, of the order of one-eighth of an inch. When the predetermined value, of the order of 850 lbs. per square inch, the four-way valve 30 is moved to a position, Fig. 1, to admit fluid pressure from pump 18 by way of lines 31, 31a to the upper end of the cylinder 24 associated with ram 16 to apply against the piston 26 a forming pressure of the order of 1,100 lbs. per square inch. The pressure of ram 16 exceeds that of the mandrel pressure of ram 14, there will be movement of the tube blank.
into the forming portion of the die. By suitably lubricating the forming surfaces and by using a metal dissimilar to that of the tube blanks, the friction developed during the forming of the tube blank is decreased and a differential of pressure of the order of 200 lbs. per square inch will be found adequate for the bending of many tube blanks to desired dimensions of curvature.

During the progress of the tube blank 10 through the forming dies, the pressure on the rubber-like mandrel 12 is maintained at its high initial value as by the setting on a relief valve 27 which is connected to the line 22 and which is arranged to discharge into the supply tank for the pump unit 18 as indicated by the line 32. The lower end of cylinder 24 beneath piston 26 is arranged to discharge into the supply tank as indicated by lines 33 and 34.

It has been found that the high pressure maintained on the rubber-like mandrel 12 causes it to exhibit the characteristics of a liquid and is effective uniformly to apply pressure on the inner surface of the tube blank 10 to maintain all upon the formed tube during formation. It has been found that instead of a thinning of the metal, as frequently occurs in forcing tube blanks over mandrels, there has been attained a cold flow of metal in all regions of the tube blank where one would expect a thinning to occur. The end result is that there is a thinning of the wall of the tube within the region of smaller radius. In the region of larger radius at the outside portion of the tube bend, there is an adequate flow of metal and such that the wall thickness of the end product approximates that of the tube blank. Any thinning which does occur is of such slight character that the thickness of the elbow or end product is adequate to meet the established standards for the maximum permissible wall reduction.

In the shaping of ⅞" tube blanks into full 90° return bends, and with a wall thickness for the tube blank of .065 inch, it has been found that a wall thickness of .059 inch in the region of greatest radius is maintained. Thus, the flow of metal has been adequate to prevent thinning of the metal at the outside portion of the bend by amounts exceeding the permissible limits of accepted industry standards.

In Fig. 2 the parts have been illustrated after completion of the tube-forming operation and the four-way valve 30 has been turned 90° from its position in Fig. 1. Before rotation of the four-way valve from its position of Fig. 1, the pressure applied by the pistons 23 and 26 may now be simultaneously increased and equalized in order to raise the pressure on the rubber-like mandrel 12 and upon the formed tube blank 10.

The pressure applied to the piston 23 is increased by raising the setting on relief valve 27 from 850 lbs. per square inch to 1,100 lbs. per square inch. By suitably adjusting the settings of relief valves 20 and 27, any desired differential of pressure may be applied to the tube blanks and any desired final finishing or sizing pressure may likewise be established. It will be understood that particular pressures will be selected on the basis of the material and wall thickness of the tube blanks.

By so elevating the pressure on the rubber-like mandrel 12 and on the tube blank 10, the shaped tube blank is strengthened against all portions of the die 11. There is thus assured that it is brought to the exact size of the die 11. Thereafter the hydraulic pressure is reduced on both cylinders 19 and 24, the die 11 opened, and the shaped tube blank 10 removed. The rubber-like mandrel 12, by reason of its elasticity, returns to its initial size and is readily removed from the shaped tube blank or bend. In this connection, it will in general be desirable to dip the rubber-like mandrel 12 in a lubricant, such as hydraulic fluid, before the die shaping operation. This aids in the insertion of the rubber-like mandrel 12 into the tube blank 10, and it also aids in its removal from the final bend. In many cases no pressure is required for its removal. It fails by gravity from the formed fitting.

By turning valve 30 ninety degrees from the position illustrated in Fig. 1 to that shown in Fig. 2, the lines 31 and 33 will be connected as will lines 31a and 34, the latter lines forming a discharge to the supply tank. Thus, fluid pressure from pump 18 may be applied by way of lines 31 and 33 to the lower end of cylinder 24 to return piston 26 to its original upper position of Fig. 1 preparatory to another tube-forming operation. The cylinder 19 need only be provided with the single line connection 22 at the right-hand end of the cylinder as the piston 23 will be returned from the position shown in Fig. 1 to the position shown in Fig. 2 by the action of piston 26 in cylinder 24. If desired, a drain connection may be provided at the left-hand end of cylinder 19 to permit the escape of any fluid leakage around piston 23 from the right-hand end of the cylinder 19.

In practicing the invention, it has been found that tube blanks can be formed at lower cost than with other processes which have been tried and with the surprising result of a better product in terms of uniformity of wall thickness and particularly in the saving of materials. Each tube blank is open-ended and of a length requiring a minimum loss of material in the final finishing operation. The end of the tube blank 10 engaged by the pressure member 17 will rarely require any finishing operation since the end surface thereof is maintained flat and square by the engagement thereof with the shoulder 17c. At the leading end of the tube blank 10 only a small amount of metal need be removed to bring it to its final dimension with a flat and square surface.

Referring now to Fig. 3, a preferred construction for the die cavity has been illustrated as comprising a pair of dies 11a and 11b hinged at 11c and 11d. In Fig. 3 the dies have been shown in the open position. Preferably, each tube blank is inserted while the dies are in the open position as, for example, in the die 11a. The die 11b is then moved to the closed position and pins are inserted through the openings in the ears rigidly secured as by welding to the die member. Of course, when each tube has been formed and shaped, the pins are removed and the dies returned to the open position of Fig. 3 for removal of the shaped tube blank therefrom. Instead of utilizing the hinge type of construction, one die member can be mounted on the ram of the press with the other die member stationary. Thus, the ram itself may be used to open and close the dies and to maintain them closed during the shaping operation. This is the preferred structure for quantity production.

The flexible linkage 15 of Figs. 1 and 2 may take various forms, the structure of Fig. 4 being exemplary of one satisfactory arrangement. In Fig. 4 it will be observed that the leading end 15a which is engaged by the end of ram 14 is circular. The flexible portion of the linkage 15 comprises a plurality of sections or units, each comprising a ring member 15b having a central opening therethrough to receive a connecting member 15c. Fig. 6, the diameter of the opening of ring member 15b being greater than the diameter of member 15c and the maximum outside diameter of the ring 15b being slightly smaller than the minimum diameter of the die cavity so that the linkage can readily traverse the arcuate shaping surface section of the die. The forward end of member 15c is provided a section having an opening 15f which is adapted to receive a pin 15e. The other end of member 15c is bifurcated, and each projection thereof has an opening 15/ adapted to be aligned with the
opening 15d in an adjacent connecting member 15c, the forward end of the latter adapted to be positioned between the bifurcated sections of the preceding connecting member 15c. The aligned openings 15f and 15d of the adjacent connecting members 15c are adapted to be pinned together by pin 15c, Figs. 4 and 5. As may be seen in Fig. 6, the opposite faces of the ring member 15b are provided with grooves to engage the sides of the pins 15e and thus are held in spaced relation by the pins 15e. When the linkage 15 is flexed, the rings 15b as well as the connecting members 15c will pivot about the various pins 15e extending through their midportions. As may be seen in Figs. 4 and 5, both the floating piston 13 at the trailing end of the linkage 15 as well as the leading end member 15a of the linkage are provided with recesses and grooves to receive the corresponding ends of the linkage 15 and engage the end pins 15e thereof.

In Figs. 4-6 the ring elements 15b in that embodiment of the linkage 15 are of reduced width at opposite sides thereof, i.e. top and bottom, thus permitting the linkage 15 to flex in either of two directions. In the modification 15' shown in Fig. 7, only one side of the rings 15b' has been provided with a reduced width as indicated at the top side of the rings. All of the other elements of the modified linkage 15' shown in Fig. 7 are identical with those illustrated in Figs. 4-6. The reduced width side of the rings 15b' will be disposed along the inside bend in the die 11 in order that the narrow sides may move toward each other as they pass around the bend in the elbow, whereas the opposite wider sides of rings 15g will move apart as they pass along the outside of the bend in the elbow. Thus, the flexible linkages 15 and 15' are both adapted to traverse a bend such as the bend illustrated in the die 11 in Fig. 3. However, in the embodiment shown in Figs. 4-6, either narrower sides of the rings 15g may be disposed adjacent the inside curve in the bend as the linkage 15 may be bent in either of two directions, whereas the linkage 15' is adapted to be bent in one direction. To aid the linkages 15 and 15' in traversing the die cavity, it will be noted that the outer surfaces of the side walls of rings 15b and 15b' are curved, the radii of curvature being such as to avoid interference of the rings 15b or 15b' with the surface of the die cavity as they traverse the bend in the die.

In the foregoing description there has been frequent reference to a rubber-like material which under pressure exhibits the characteristics of a liquid under pressure. While the foregoing terminology is self-explanatory, it is used to cover materials of many kinds. For example, materials will be suitable which have a pressure-plastic characteristic, meaning, under Pascal's law, that when pressure is applied to one portion of a confined body thereof, the same pressure will appear throughout all of the external surface thereof. Any rubber-like or pressure-plastic material will be suitable when it meets the foregoing tests since it then acts within the confined metal-shaping cavity in the same way as a liquid.

Plastic materials which comply with the foregoing definition include natural rubber, synthetic rubber (polymercaptan base), including both the isomerized and chlorinated. Other suitable plastics include polyisprene and the polyvinyl chlorides in their plasticized form and which are sold under various trade names such as Koroseal and Vinylite.

Mention has already been made of the desirability of providing a metal for the die cavity dissimilar to that of the tube blank. Where tube blanks of stainless steel are used, the die cavity may be formed of an alloy of aluminum bronze available on the market from Ampco Metal, Inc., under the trade name of "Ampco.

Where tube blanks are of steel, the Ampco metal will be satisfactory for the shaping surface of the die, and when copper blanks are to be used a hardened aluminum alloy has been found satisfactory.

The foregoing examples will be adequate to illustrate that the dissimilarity between the metal of the die and that of the tube blank will be such as to minimize and prevent seizing, galling and scoring of the tube blank as it is forced through the shaped surface.

Any of the usual drawing compounds utilized for dies will be found suitable, a preferred lubricant being Houghton Draw Oil No. 3105 for stainless steel tube blanks.

With the above understanding of the invention, it will be understood that many variations may be made within the spirit and scope of the appended claim.

What is claimed is:

In the art of bending open-ended tube blanks in a shaping die, the method comprising the steps of filling the tube blank with a rubber-like material having the characteristic of a liquid under pressure, applying a pressure to one end of the tube blank and to the corresponding end of the rubber-like material, applying an oppositely-directed pressure of different magnitude at the other end of the tube blank and to its corresponding end of the rubber-like material to create a high pressure on the rubber-like material in the tube blank acting in an outward direction on the walls of the tube blank to prevent wrinkling and for the production of compressive forces to the substantial avoidance of tensional forces otherwise producing cracks and other fractures of the tube blank during formation of the tube blank into a tube bend, maintaining the application of pressures at the opposite ends of the rubber-like material so that the magnitude of the differential of pressure moves the tube blank and its filling of rubber-like material into the shaping die to form the tube blank into a tube bend, thereafter raising the lower one of the pressures applied to the rubber-like material to increase the outward pressure on the walls of the tube bend to force the walls of the tube bend outwardly and uniformly into engagement with the surface of the shaping die for sizing the tube bend, reducing said pressures at both ends of the tube bend on the rubber-like material, and removing the rubber-like material from the sized tube bend.

References Cited in the file of this patent

UNITED STATES PATENTS

1,647,526 Kenney November 1, 1927
1,683,573 Mueller et al. September 4, 1928
1,943,978 Luce January 16, 1934
1,947,611 Mioklie February 20, 1934
2,615,411 Cleveenger et al. October 28, 1952
2,701,002 Arbogast February 1, 1955
2,715,432 Wurzbarger August 16, 1955