METHOD AND APPARATUS FOR PRODUCING FINNED METAL TUBING
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20 Claims. (Cl. 72—56)

The present invention relates to method and apparatus for producing finned metal tubing. It is an object of the present invention to provide method and apparatus for producing finned metal tubing which eliminates the occurrence of split fins due to work hardening of the metal prior to finning. It is a further object of the present invention to provide a method and apparatus for producing finned metal tubing, preferably tubing having a relatively large number of fins per linear inch and formed of relatively thin-walled stock which eliminates the problems of partial collapse or squaring of the tube as has previously occurred.

It is a feature of the present invention to provide a method and apparatus for finning metal tubing which comprises the step of reducing the diameter of a short section of the tube by an operation characterized by the substantial absence of work hardening, followed by the movement of inclined finning rolls into engagement with the reduced section of the tubing.

It is a further feature of the present invention to provide a method and apparatus for finning metal tubing having plain sections or lands the outside diameter of which is at least as great as the outside diameter of the fins on the finned portions thereof, in which the initiation of the finning operation takes place at a reduced section of tubing, characterized by the absence of objectionable work hardening in the reduced section of tubing.

It is a further feature of the present invention to provide a method and apparatus for finning metal tubing in which the diameter of a short section of tubing is reduced by electromagnetic swaging, inclined finning rolls are moved into engagement with the outside diameter of the tubing at the reduced portion, the finning rolls are driven in rotation, and the tube rotated and axially advanced to progressively reduce and simultaneously form fins on the section of tubing next adjacent to the reduced section thereof.

It is a further object of the present invention to provide apparatus for finning tubing which comprises a mandrel, a plurality of finning rolls surrounding said mandrel and having their axes inclined slightly with respect to the axis of the mandrel, an electromagnetic swaging coil adjacent said mandrel and located concentrically with respect thereto, and tube positioning means movable axially of the mandrel and including means for gripping and releasing tubing to effect axial advance and retraction thereof.

It is a further object of the present invention to provide apparatus as described in the preceding paragraph, comprising means for controlling the advance and retraction of tube positioning means comprising a fluid actuated piston and cylinder device, solenoid actuated valve means for controlling the operation of said piston and cylinder device, and limit switches for controlling, advancing, and retracting movement of the tube positioning means to move a plain section of tubing into the swaging coil, and after a swaging operation to move the reduced portion of the tubing into the space between the finning rolls.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating a preferred embodiment of the invention, wherein:

FIGURE 1 is an elevational view, largely diagrammatic and partly in section, of the tube finning apparatus.

FIGURE 2 is an enlarged elevational view showing the relationship between a finning roll and a reduced portion of tubing.

FIGURES 3, 4 and 5 are sequential diagrammatic elevational views illustrating the method and operation of the apparatus for finning the tubing.

FIGURES 6 and 7 are fragmentary sectional views showing a tube reduced section of different shape.

In the past considerable difficulty has been encountered in producing fine pitch fins on tubing, particularly where it is attempted to produce such fins on relatively thin-walled tubing. Conventional apparatus for finning as it is now known in the industry usually comprises a mandrel over which the tubing is advanced, and a plurality, usually three, finning rolls the axes of which are inclined slightly with respect to the axis of the mandrel. Commonly, finning rolls of this type are assembled from a plurality of discs and the angle of inclination is such that the engagement between the rolls and the tubing rotates the tubing and causes it to advance axially, while forming one or more helical fins thereon. Rolls of this type are shown in U.S. Greene Patent 2,868,046.

With this type of equipment it is possible to effect radial in and out movement of the rolls so that it is possible after finning a length of tubing to move the rolls outwardly and to thereafter advance the plain tube to leave a plain section or land thereof, followed by a second finned section resulting from moving the rolls radially inwardly into operative engagement with the tubing. It is commonly desirable to provide the plain or unfinned lands with an outside diameter at least as great as the outside diameter of the fins on the finned section of the tubing. This will permit movement of an intermediate plain or unfinned portion or land into an opening in a header or plate.

In the past, the initiation of a finning operation at an intermediate portion of tubing involved moving the rolls radially inwardly while rotating, thus initiating driven rotation of the tubing while at the same time reducing the diameter of the tubing to a dimension determined by the mandrel. In many cases this operation resulted in partial collapse of the tubing or squaring before the finning operation got under way. If the operation was carried out with a relatively slow inward radial movement of the rolls, an undesirably long portion of the tubing adjacent the land became a transition zone before full fin height was achieved.

One of the reasons why squaring of the tubing occurred is because the sequence of finning discs involves not only an increase in diameter but a variation in shape.

The first disc, or in some cases the first few discs, may be of relatively small diameter with relatively sharp peripheral portions capable of initiating a cutting action. Thereafter, the sequence of discs, of progressively increasing diameters, shapes and forms the material of the tubing into the desired continuous helical fin or fins. Accordingly, the final finishing disc is designed to operate on a space between adjacent fins only after this space has been sequentially worked by all of the remaining discs in the roll. If it is attempted to force this final finishing disc directly into an unworked or plain portion of the tubing, it is not operating as it was intended nor is its form suitable for such an operation. Accordingly, large forces are developed which in many cases result in collapse of the tubing or squaring thereof.

The difficulties previously encountered are avoided in the present instance by reducing a short section of tubing
by an operation which eliminates objectionable work hardening of the metal both in the reduced zone and in the transition zone at the ends of the reduced zone. Since this section of tubing is already reduced, the problem of tube collapse or squaring resulting from radial inward movement of the rolls is of course completely eliminated. Moreover, since this reduction of the section of tubing is accomplished without objectionable work hardening, the initiation of the finning operation permits a proper progressive fin formation in conjunction with a simultaneous tube reduction so that the finning operation does not result in splitting. Moreover, since the section of tubing which is reduced in accordance with the present invention is only of a length sufficient to accommodate part or all of the finning rolls, full fin height is achieved substantially closer to the shoulder of the adjacent land than has hitherto been possible, particularly with thin-walled stock.

Referring now to the drawings, the apparatus which is employed in carrying out the method disclosed herein comprises a finning head 10 having a plurality of roll arbors two of which are indicated at 12 and 14. Extending outwardly from the finning head 10 is a cylindrical member 16 over which tubing indicated generally at T is advanced in a finning operation.

The arbors, two of which are indicated at 12 and 14, are preferably three in number and each is inclined to the axis of the mandrel 16 at a small angle. The relationship such that circumferential finning discs, indicated generally at 18 in FIGURE 2, carried by the finning rolls indicated generally at 19, are inclined to the length of the tubing so as to produce helical finned structure including one or more fins 20 thereon.

In alignment with the mandrel 16 and preferably surrounding the mandrel 16 thereon there is an electromagnetic swaging device 21 including a coil 22 wound over a carrier 24 and adapted to be energized by a very brief pulse so as to induce electromagnetic forces which will collapse a short section of tubing onto the mandrel 16, thus producing a reduced section of the character indicated at 26 in FIGURE 2.

The electromagnetic swaging coil 22 may be of the type disclosed in U.S. Harvey Patent 2,976,907, and no further description of its operation is believed necessary herein.

However, it may be stated that the swaging force developed by the coil may be controlled by controlling the applied electrical energy. In fact, it is possible to produce satisfactory reduction in the short section of tubing by a control of the electromagnetic swaging force without limiting tube reduction by the mandrel 16. In other words, if the swaging coil is properly designed and controlled such that the mandrel 16 need not extend into the interior of the coil. On the other hand, the use of the mandrel 16 in the swaging coil provides a convenient gauge for limiting reduction of the short section of tubing. Care must be taken however, to avoid the application of excessive swaging force since this would tend to prevent longitudinal advance of the tubing over the mandrel 16.

Associated with the electromagnetic swaging device 21 and the finning head 10 is tube positioning means including a clamp indicated generally at 28 including clamping jaws 30 and 32 adapted to be moved toward and away from each other in clamping and releasing strokes by a tube clamping device 34. The clamp 28 is connected to means for effecting movement thereof axially of the tubing T and this means is illustrated as comprising a fluid actuated piston and cylinder device 36, the piston of which in FIGURE 1 is indicated at 38 as connected to the clamp 28. Movement of the clamp 28 is controlled by supplying fluid to one end or the other of the cylinder of the piston and cylinder device, and in turn is controlled by a solenoid actuated valve 40, the actuating solenoids of which are controlled by limit switches 42, 44 and 46. The tube positioning clamp 28 has a switch actuating element 48 thereon effective to engage the switch actuating arms illustrated in the figure, as will subsequently be described in detail.

Referring now to FIGURES 3, 4 and 5, in FIGURE 3 the tube T is illustrated in a position where a portion 50 has been finned to the desired length and in which the next succeeding portion is to be left as a land. At this time the finning rolls 19 only one of which is shown in these figures, are in their innermost radial position and are progressively reducing the diameter of the tube T until its inside diameter engages the mandrel 16 while the finning discs also progressively form the fins 20 thereon. In FIGURE 3 it will be noted that the clamp 28 is in position so that the element 48 thereof has actuated the finger of limit switch 42. It will further be observed that the end of the tube T has at this time engaged the finger of a fourth limit switch 52 which is the signal for the initiation of the operation which causes the next following section of tubing to be left in the form of plain tubing of unreduced diameter or a land. Upon actuation of the limit switch 52 the arbors, of which only the arbor 12 is shown in FIGURES 3–5, are moved abruptly radially outwardly, thus leaving the tubing in the position illustrated without advance or rotation thereof. Simultaneously, the jaws 30 and 32 of the clamp 28 move inwardly and grip the tubing T. This gripping normally takes place on a previously finned portion of the tube although this is not an essential requirement, and the jaws 30 and 32 are capable of gripping or clamping the tube either on a plain or finned portion thereof.

After the gripping arm 34 is moved to the right as seen in the figures until the element 48 thereon engages the operating finger of the limit switch 46, as illustrated in FIGURE 4. Operation of the limit switch 46 operates the valve 40 so as to terminate admission of fluid to the left hand end of the piston and cylinder device 36 and thus stops travel of the tube T.

As best seen in FIGURE 1, the location of the limit switches is related to the spacing and dimensions of the finning rolls and tube swaging device. As seen in this figure the dimension X is the spacing axially of the tube between the left hand end of a finning roll 19 and the right hand end of the swaging coil 22. The dimension Y is the axial spacing between the right hand end of a finning roll 19 and the right hand end of the swaging coil 22. The limit switches 42 and 46 are separated by a dimension equal to the dimension X plus the desired length of land to be provided on the tubing. The limit switches 44 and 46 are separated by the dimension Y.

With the parts in the position illustrated in FIGURE 4, a very brief pulse of electrical energy is supplied to the swaging device 21. This pulse is in the micro or millisecond range and exerts a controllable force upon the tube which can reduce its diameter to the required size. In FIGURE 4 the material of the tube T is shown as reduced at 54, thus leaving a land of desired width as indicated at 56.

While reduction of the tubing by electromagnetic swaging against a mandrel is a simple way to control the dimensions of the swaged section of the tubing, it is possible by proper design of the swaging coil to reduce a section of tubing as required without requiring the presence of a mandrel to limit inward movement of the tubular stock. Moreover, however, proper design of the swaging coil is possible to provide a particular required shape in the reduced section of the tubing.

Thus for example, in FIGURE 6 a portion of a tube T3 is illustrated having a reduced section 64 which is conical in shape having its larger diameter to the right as seen in the figure. In FIGURE 7 the tube T3 is illustrated in which the reduced section 66 is of greater diameter to the right but which in cross-section is concave curved as illustrated in the figure.

After the reduction of tube diameter by the swaging device 21, the valve 40 is operated to admit fluid under pressure to the right hand end of the piston and cylinder
device 36 to move the clamp 28 to the left where the element 48 engages the actuating finger of the limit switch 44. This returns the reduced section 43 of the tube T to initial position intermediate the plurality of finning rolls, one of which is indicated at 19. At this time the finning rolls are moved radially inwardly to bring the peripheral portions thereof into the reduced tube section 54 substantially as illustrated in FIGURE 2. It will be noted at this time that the tube T is illustrated designed for movement to the left so that the previously finned portion 20 and land portion 56 have already passed through the finning zone determined by the location of the finning rolls 19.

In the fin forming operation the engagement between the peripheral portions of the finning discs 18 is relied upon for rotating the tube T and for imparting axial advance thereto. Accordingly, the initial position of the finning roll 19 with respect to the reduced section 26 of the tube must establish this driving connection. As shown in FIGURE 2, the initial or cutting disc or discs, here designated 58, of the roll 19 is shown as in engagement with the shoulder 60 provided at the following end of the reduced section 26.

Alternatively, the finning rolls 19 may be moved inwardly to a position in which the final finning rolls (shown in FIGURE 2) are engaged relatively themselves somewhat into the material of the tube T at the reduced section 26. However, the finning discs are not capable of producing full height fins at this time because the material on which they are working has not progressed through all of the preceding discs required for the production of full fin height. On the other hand, a full fin production of useful height is entirely practical. Moreover, throughout the transition zone from the land section 56 to the following finned section, there will be an increase in fin height and an improvement in form finish until full fin height and perfect fin form is achieved when the material of the tube at the shoulder 60 arrives in the zone of operation of the final fin forming disc seen at the left of the roll in FIGURE 2.

In practice, the short section of the tube which is swaged by electromagnetic forces may have a length from ½ inch to 1½ inches. The finishing discs need not significantly impinge the tube until a groove has been started for them by the preceding cutting discs. The swaged section is not significantly hardened during the swaging process so that fins formed at the transition zone between the swaged section and the following plain section are not split. In general, the resulting start is one in which the cutters initiate their cut in virgin metal and the grooves which they start then proceed to be further worked by the succeeding finishing discs.

There are several advantages of this operation. In the first place, the finishing discs, and particularly the final finishing discs, do not engage the raw unreded stock before the cutter discs and therefore are not subjected to the abnormal stresses encountered in attempting to immediately extrude a full fin before preconditioning the metal with the preceding cutting discs and partial fin forming disc. Thus, disc breakage is materially reduced and fin life is materially extended.

Since the cutting discs are fully engaged at a distance which is normally less than 1 inch back from the adjacent end of the preceding land, full fin height is realized at this point and the transition section between the adjacent land section and the first full height fin is shorter than has been previously produced.

In the case of the collapse or squaring of the tube, as has sometimes been encountered, is virtually eliminated since the finishing discs are not called upon to perform an intermediate tube reducing operation. This means a less critical machine setup, less setup time, and greater production as compared to those cases where finning speed has necessarily been reduced from standard in order to eliminate squaring at the starts.

Under present conditions, difficulty is encountered when a set of completely new discs is installed on a machine. It is found that this often causes tube collapse or squaring until the new set of discs has worn in. With the present operation it is generally possible to install a new set of discs and to start producing tubing immediately.

As previously mentioned, an important advantage of the present invention is the possibility of producing fins on light-walled tubing with the same ease as has hitherto encountered with heavy-walled tubing. Intermediate lands in light-walled tubing may also be produced by the present method and apparatus. This is because squaring on the start has generally been one of the obstacles in producing this product.

Since the fin rolling operation initiates with the finning rolls at their final radial spacing with respect to the mandrel and tubing, theoretical head angle requirements are more nearly met. It has been recognized that in prior practice the head angle of the roll should be continuously changed as the discs penetrate the mandrel because of the variation in helix angle in accordance with variations in operating diameter. With the present method and apparatus the swaged section permits the discs to enter the tube at their full penetration and required depth and therefore the varying angle requirement is not necessary.

The present method and apparatus may be adopted on existing equipment with little or no change. If finned tubing is to be produced without any intermediate lands it may be desirable to perform the swaging operation on a separate mandrel from that used in the finning operation.

The drawings and the foregoing specification constitute a description of the improved method and apparatus for producing finned metal tubing in such full, clear, concise and exact terms as to enable any person skilled in the art to practice the invention, the scope of which is indicated by the appended claims.

What we claim as our invention is:

1. The method of finning metal tube which comprises reducing the diameter of the tube by the application of electromagnetic forces to a section of the tube, thereafter moving a set of finning rolls radially inwardly to contact the reduced tube section over a mandrel, rotating the tube and finning rolls in timed relation and advancing the tube to bring an unreduced length thereof progressively into position to be acted on between the finning rolls and mandrel.

2. The method of finning metal tube which comprises reducing the diameter of the tube by the application of electromagnetic forces to a section of the tube against a mandrel, thereafter moving a set of finning rolls radially inwardly to contact the reduced tube section over the mandrel, rotating the tube and finning rolls in timed relation and advancing the tube to bring an unreduced length thereof progressively into position to be acted on between the finning rolls and mandrel.

3. The method of finning metal tube which comprises reducing the diameter of the tube by the application of electromagnetic forces to a section of the tube to produce a reduced section of tapered diameter, thereafter moving a set of finning rolls radially inwardly to contact the reduced tube section over a mandrel, rotating the tube and finning rolls in timed relation and advancing the tube to bring an unreduced length thereof progressively into position to be acted on between the finning rolls and mandrel.

4. The method of finning metal tube which comprises positioning the tube over a mandrel, reducing the diameter of a section of the tube by the application of electromagnetic forces thereto at a point remote from said mandrel, thereafter moving the tube axially to position the reduced section over the mandrel, thereafter moving a set of finning rolls radially inwardly to contact the reduced tube section over the mandrel, rotating the tube
and finning rolls in timed relation and advancing the tube to bring an unreduced length thereof progressively into position to be acted on between the finning rolls and mandrel.

5. The method of finning metal tube which comprises positioning a plain tube over a mandrel with substantial radial clearance with respect to the mandrel, reducing the diameter of a short section of tube by brief application of electromagnetic forces to the tube to reduce the short section, moving a set of inclined finning rolls radially inwardly of the reduced tube section to establish a driving relation between the rolls and tube in timed relation and simultaneously advancing the tube axially first to bring an unreduced portion thereof into operating relation with the rolls, and thereafter to continue to advance and rotate the tube to form helical fin structure thereon.

6. The method of finning metal tube which comprises positioning a plain tube over a mandrel with substantial radial clearance with respect to the mandrel, reducing the diameter of a short section of tube by brief application of electromagnetic forces to the tube to reduce the short section against the mandrel, moving a set of inclined finning rolls radially inwardly of the reduced tube section to establish a driving relation between the rolls and tube, rotating the rolls and tube in timed relation and simultaneously advancing the tube axially first to bring an unreduced portion thereof into operating relation with the rolls, and thereafter to continue to advance and rotate the tube to form helical fin structure thereon.

7. The method of forming a finned metal tube having an intermediate land whose outside diameter is at least as great as the outside diameter of the fins on the tube which comprises rotating a tube on a mandrel smaller than the initial inside diameter of the tube between inclined, each having a series of progressively larger discs to reduce the diameter of the tube and to form helical fins thereon, shifting the rolls abruptly radially outwardly of the tube into a clearance condition, thereafter reducing a short section of the tube separated axially from the previously finned portion by a distance equal to the desired length of land, moving the rolls radially inwardly into driving relation to the reduced tube section, rotating the rolls and tube in timed relation and advancing the tube to bring the adjacent unfinned and unreduced portions progressively into engagement with the rolls to reduce the tube against the mandrel and to form helical fin structure thereon.

8. The method of claim 7 in which the reduction of the short tube section is accomplished by the brief application of electromagnetic force directly thereto.

9. The method of forming a finned metal tube having an intermediate land whose outside diameter is at least as great as the outside diameter of the fins on the tube which comprises rotating a tube on a mandrel smaller than the initial inside diameter of the tube between inclined finning rolls each having a series of progressively larger discs to reduce the diameter of the tube and to form helical fins thereon, shifting the rolls abruptly radially outwardly of the tube into a clearance condition, thereafter reducing against the mandrel a short section of the tube separated axially from the previously finned portion by a distance equal to the desired length of land, moving the rolls radially inwardly into driving relation to the reduced tube section, rotating the rolls and tube in timed relation and advancing the tube to bring the adjacent unfinned and unreduced portions progressively into engagement with the rolls to reduce the tube against the mandrel and to form helical fin structure thereon.

10. The method of claim 9 in which the reduction of the short tube section is accomplished by the brief application of electromagnetic force directly thereto.

11. Tube finning apparatus comprising a mandrel, a finning head having a plurality of arbors located around said mandrel and inclined at a small angle to the axis thereof and individually movable radially thereof, a set of progressively stepped cutting and fin forming discs on said arbors dimensioned when in their radially inner position to reduce the tube against the mandrel and to form helical fin structure thereon, an electromagnetic tube swaging coil in alignment with said mandrel and spaced axially therefrom, tube positioning means for moving a plain unreduced portion of tube into said coil for swaging and thereafter into the finning zone intermediate said rolls, and means for driving said rolls in rotation.

12. Tube finning apparatus comprising a mandrel, a finning head having a plurality of arbors located around said mandrel and inclined at a small angle to the axis thereof and individually movable radially thereof, a set of progressively stepped cutting and fin forming discs on said arbors dimensioned when in their radially inner position to reduce the tube against the mandrel and to form helical fin structure thereon, an electromagnetic tube swaging coil in alignment with said mandrel and spaced axially therefrom, tube positioning means for moving a plain unreduced portion of tube into said coil for swaging and thereafter into the finning zone intermediate said rolls, and means for driving said rolls in rotation.

13. Apparatus as defined in claim 12 in which said mandrel extends into said coil.

14. Apparatus as defined in claim 12 in which said tube positioning means comprises a clamp engageable with a plain or finned portion of tube, means for shifting said clamp axially of said mandrel to advance and retract a tube therefrom.

15. Apparatus as defined in claim 14 in which the means for shifting the clamp comprises a fluid actuated piston and cylinder device.

16. Apparatus as defined in claim 14 in which the means for shifting the clamp comprises a fluid actuated piston and cylinder device and three limit switches positioned to determine the retracted position, the clamping position and swaging position of said clamp, and solenoid actuated valve means controlled by said limit switches.

17. The method of initiating a finning operation on thin-walled metal tubing without producing split fins from work hardening which comprises positioning a length of tubing over a mandrel with substantial clearance therebetween, applying a pulse of electromagnetic constrictive force to a short section of tubing overlying said mandrel to reduce the inside diameter of said short section and move it into engagement with said mandrel without undesirable work hardening of the metal, thereafter supporting the reduced section of the tubing on said mandrel and radially advancing a plurality of inclined finning rolls into relatively light engagement with the outer surface of the tubing at the reduced section, driving the rolls and tubing in rotation and advancing the tubing longitudinally of the mandrel to form fins on an unreduced portion of the tubing adjacent the reduced section thereof.

18. The method of initiating a finning operation on thin-walled metal tubing without producing split fins from work hardening and without causing collapse of the tubing which comprises applying an electromagnetic constrictive force to a short section of tubing to reduce its diameter, thereafter supporting the reduced section of tubing on a cylindrical mandrel and radially advancing a finning roll having its axis inclined slightly with respect to the axis of the mandrel into engagement with the outer surface of the tubing at the reduced short section thereof, driving the roll and tubing in rotation in timed relation and advancing the tubing longitudinally of the mandrel.

19. The method as defined in claim 18 in which the reduction of the short section of tubing by the application of the electromagnetic constrictive force is sufficient to maintain an outside diameter on the unreduced and unfinned portion of the tubing which is at least as great as the outside diameter of the fins formed by the action of the finning roll.
20. The method as defined in claim 18 in which the diameter of the mandrel is approximately equal to the inside diameter of the short reduced section of tubing and substantially smaller in diameter than the inside diameter of unreduced portions of the tubing, in which the rotation of the roll against the tubing supported by the mandrel effects a progressive simultaneous reduction in inside diameter of the tubing to a dimension corresponding to the diameter of the mandrel and a progressive formation of helical fins on the tubing.

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