

[54] **FORMING TRANSVERSE CORRUGATIONS
IN A TUBULAR BLANK**

[75] Inventors: **Samuel Price**, Harpenden; **Thomas Frederick Plummer**, Kenton; **Robert James Fowler**, Kingsbury; **Edward Reuben Hill**, Arkley; **Cecil Woodward**, Hayes; **Ewart Arthur Harrington**, Edgware, all of England

[73] Assignee: **General Motors Corporation**, Detroit, Mich.

[22] Filed: **Mar. 8, 1973**

[21] Appl. No.: **339,198**

[30] **Foreign Application Priority Data**

Mar. 18, 1972 Great Britain 12778/72

[52] U.S. Cl. **72/193, 72/194, 72/370**

[51] Int. Cl. **B21d 15/06**

[58] Field of Search 72/193, 194, 224, 370;
29/454

[56] **References Cited**

UNITED STATES PATENTS

2,614,607	10/1952	Klein.....	72/194
2,714,919	8/1955	Johnston.....	72/193
2,736,284	2/1956	Jacokes.....	72/193
R12,346	5/1905	Harter.....	72/193

FOREIGN PATENTS OR APPLICATIONS

851,791	10/1952	Germany	72/224
---------	---------	---------------	--------

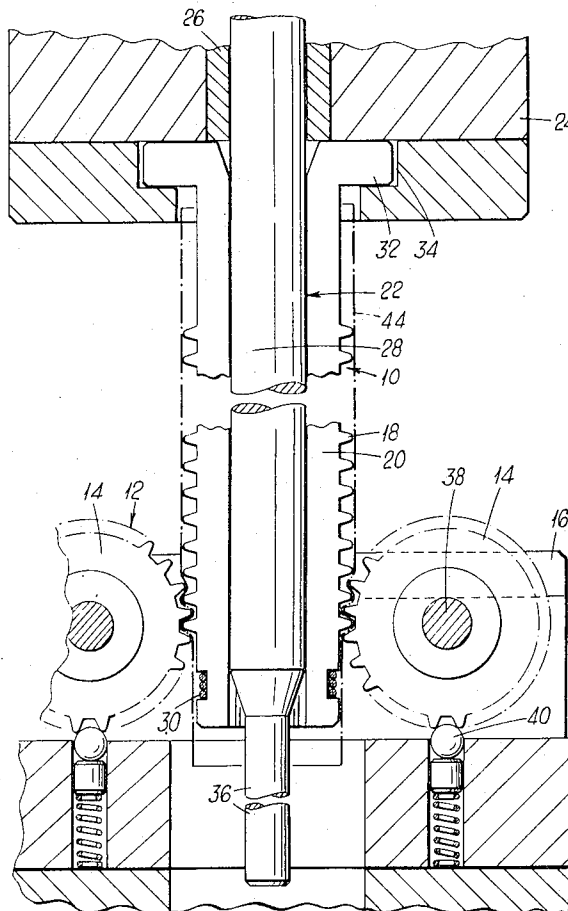
Primary Examiner—Lowell A. Larson
Attorney, Agent, or Firm—D. L. Ellis

[57] **ABSTRACT**

The drawings illustrate the forming of a tubular blank into a transversely corrugated tubular member having closely controlled axial collapse characteristics by forcing a die assembly along a corrugated centre mandrel carrying the tubular blank, whereby successive teeth of a ring of radially extending toothed wheels forming part of the die assembly index with successive corrugations of the centre mandrel with a rack and pinion type of action to form the required transverse corrugations in the interposed tubular blank, primarily by pure bending of the material of the blank. The mandrel is made up of a series of like elongate segments which are arranged around an expander plug and are selectively held in an expanded operative condition, or allowed to collapse radially inwardly for removal of the corrugated tubular member, by axial movement of the expander plug. Spring-loaded detent balls co-operate with the teeth of the individual toothed wheels to ensure correct initial positioning.

Corrugations which vary along the length of the tubular member can be produced by mounting the toothed wheels of the die assembly in slide members, and arranging for progressive variation of the radial positions of the toothed wheels during the forming operation.

6 Claims, 6 Drawing Figures



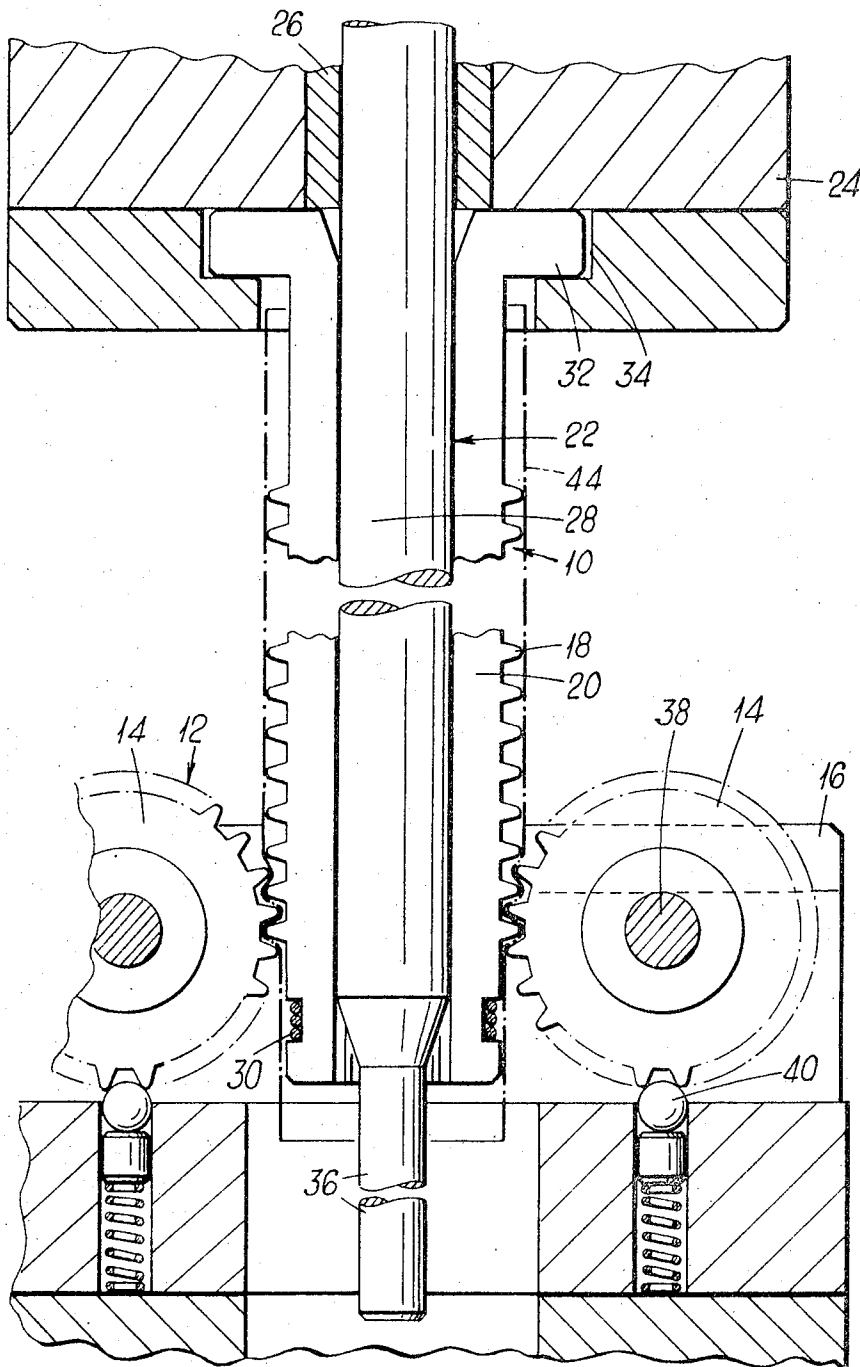


Fig. 1.

Fig. 2.

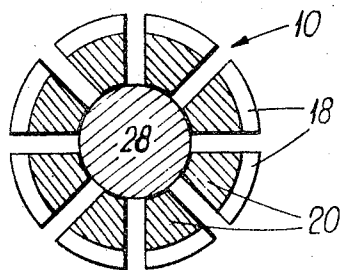
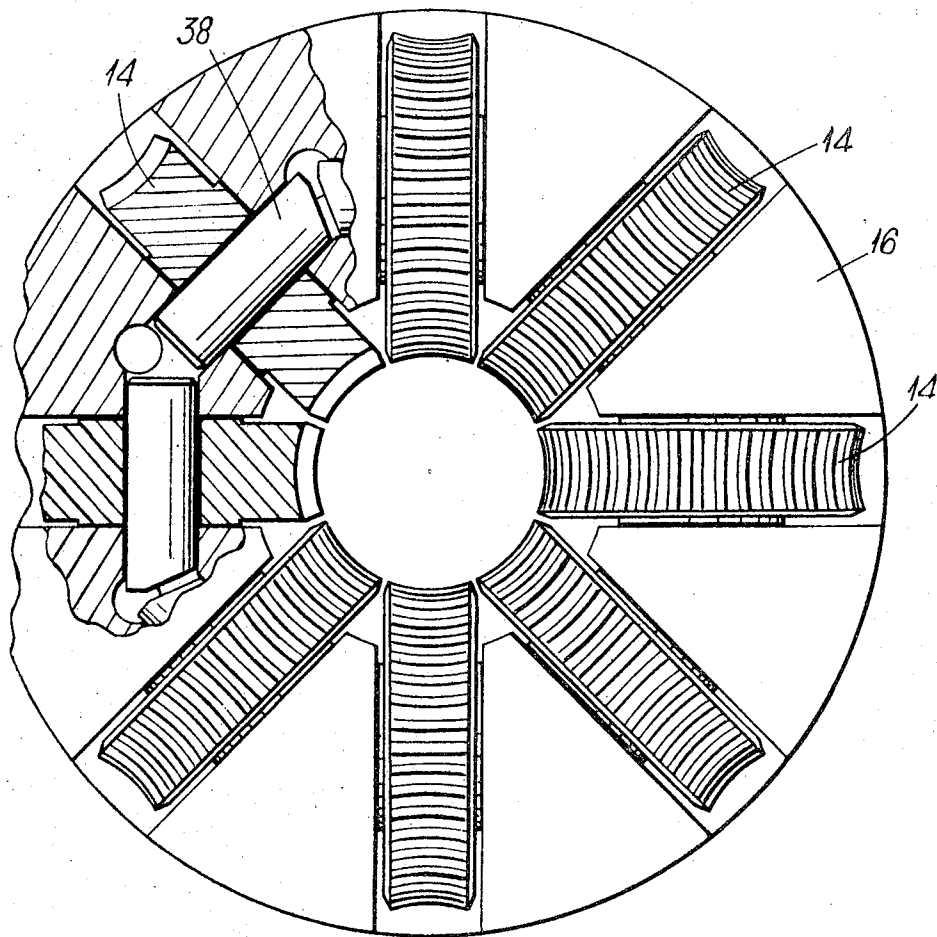


Fig. 3.

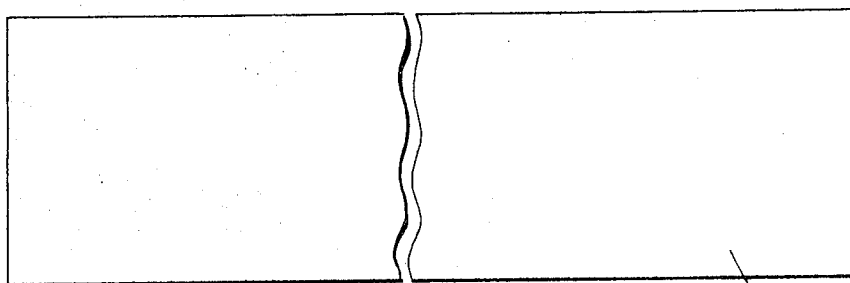


Fig. 4a

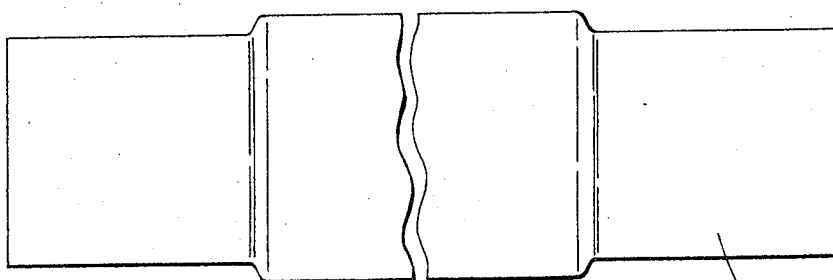


Fig. 4b

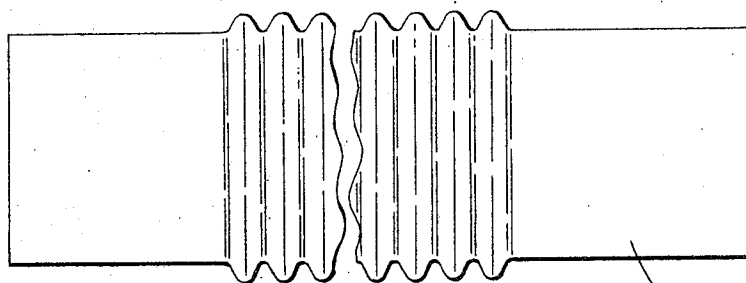


Fig. 4c

FORMING TRANSVERSE CORRUGATIONS IN A TUBULAR BLANK

This invention relates to a method of, and apparatus for, forming transverse corrugations in a tubular blank, for example for the production of transversely corrugated metal tubular members for use in an energy-absorbing steering column of a motor vehicle.

In general, the invention envisages the use of an elongate segmental collapsible centre mandrel formed externally with transverse corrugations substantially corresponding to those to be formed in a tubular blank, and a die assembly comprising a ring of toothed wheels which extend radially of the longitudinal axis of the centre mandrel and are rotatably mounted in a common holder with the axes of rotation of the rollers disposed in a common radial plane of the longitudinal axis of the centre mandrel, the circular pitch of the teeth of each wheel being equal to the linear pitch of the transverse corrugations of the centre mandrel, whereby, on relative axial displacement of the centre mandrel and the die assembly, with a tubular blank in position on the transverse corrugations of the centre mandrel, successive teeth of the ring of wheels index with successive corrugations of the centre mandrel with a rack and pinion action, to thereby cause progressive formation of transverse corrugations in the interposed tubular blank, whereafter the segmental centre mandrel may be collapsed to permit removal of the resulting transversely corrugated tubular member.

A method in accordance with the invention for forming transverse corrugations in a tubular blank comprises: positioning the blank on an externally transversely corrugated portion of an elongate segmental centre mandrel, the transverse corrugations on which substantially correspond to those to be formed in the tubular blank; effecting relative axial displacement of the centre mandrel and blank and a die assembly comprising a ring of toothed wheels which extend radially around the longitudinal axis of the centre mandrel and are rotatably mounted in a common holder with the axes of rotation of the rollers disposed in a common radial plane of the longitudinal axis of the centre mandrel, the circular pitch of the teeth of each wheel being equal to the linear pitch of the corrugations of the centre mandrel, such that the relative axial displacement of the centre mandrel and the die assembly causes progressive formation of transverse corrugations in the interposed tubular blank as successive teeth of each of the wheels index with successive corrugations of the centre mandrel with a rack and pinion action; effecting collapse of the segmental centre mandrel; and removing the resulting transversely corrugated tubular member from the collapsed centre mandrel.

Apparatus in accordance with the invention for forming transverse corrugations in a tubular blank comprises an elongate segmental centre mandrel formed externally with transverse corrugations substantially corresponding to those to be formed in the tubular blank, and a die assembly comprising a ring of toothed wheels which extend radially of the longitudinal axis of the centre mandrel and are rotatably mounted in a common holder with the axes of rotation of the rollers disposed in a common radial plane of the longitudinal axis of the centre mandrel, the circular pitch of the teeth of each wheel being equal to the linear pitch of the transverse corrugations of the centre mandrel, the

arrangement being such that, with a tubular blank held in register with the centre mandrel, around the transverse corrugations thereof, and with all the toothed wheels in an initial position, relative axial displacement of the centre mandrel and the die assembly causes progressive formation of transverse corrugations in the interposed tubular blank as successive teeth of each of the wheels index with successive corrugations of the centre mandrel with a rack and pinion action, the apparatus also comprising means actuable to effect collapse of the segmental centre mandrel for removal of the resulting transversely corrugated tubular member.

Thereby, it is not necessary to provide a drive for the toothed wheels, because the rack and pinion action produced by the relative axial displacement of the centre mandrel and the die assembly provides the required rotary movement of the wheels, in synchronism with one another.

For all normal purposes the toothed wheels will be identical in size and configuration.

To provide correct initial positioning of the toothed wheels, spring-loaded balls or other detent arrangements are conveniently mounted on the die assembly and arranged to co-operate with adjacent teeth of the respective toothed wheels.

An abutment, specifically the leading external transverse corrugation on the centre mandrel, is conveniently used for the initial feeding-in of the tubular blank to the circular throat ("nip" region) between the centre mandrel and the toothed wheels. Thereby, during the progressive formation of the transverse corrugations in the tubular blank, the extra material required for forming the corrugations can be allowed to flow over the centre mandrel from the free end, namely the opposite end to the abutment.

To achieve the relative axial displacement of the centre mandrel and the die assembly, either one of these may be moved, and the other will generally be maintained stationary. Thus, the centre mandrel may be moved and the die assembly may be maintained stationary, or the die assembly may be moved and the centre mandrel maintained stationary.

The tubular blank will generally be made of metal, which may be ferrous metal, for example steel, or non-ferrous metal, for example aluminum or copper or a copper alloy. The metal of the blank may be annealed or subjected to other heat treatment before or after formation of the corrugations, depending on the properties required, and correspondingly the wall thickness, the corrugated length, and the composition of the blank may be varied, depending on the properties required in the resulting corrugated tubular member.

The tubular blank (and correspondingly the centre mandrel) will generally have a circular cross-section, although a polygonal cross-section would alternatively be feasible. Corresponding to such circular cross-section, the crests of the teeth of the toothed wheels are preferably concave between the tooth flanks, with the same curvature as the circular crests of the transverse corrugations of the centre mandrel.

The number of toothed wheels is preferably the same as the number of segments of the centre mandrel, with the gaps between the inner peripheries of the toothed wheels (at the throat of the die assembly) being radially aligned with the gaps between the individual segments of the centre mandrel, whereby good resistance of the resulting corrugated tubular member to bending forces

can be achieved. For example, there may be eight toothed wheels in the die assembly, and correspondingly eight segments making up the centre mandrel.

If the tubular blank is not to be corrugated throughout its length, it may have one or both of its end portions of reduced diameter, formed for example by the use of swaging dies. This is normally required for instance in the case of tubes to be used for energy-absorbing steering columns, to allow bearings or tube extensions (for example) to be fitted.

The centre mandrel may be disposed in a vertical position or in a horizontal (or other) position. To expand the mandrel, hydraulic or mechanical means may be used. Thus, the centre mandrel may have a circular external cross-section and be made up of a plurality of like segments which surround an expander plug that is slidably mounted in a mandrel support housing, with the expander plug including a full-diameter generally cylindrical portion which in a first position of the expander plug holds the segments of the centre mandrel in an expanded, operative position, means being provided to limit radially outward movement of the segments of the centre mandrel, and the expander plug may also include a smaller-diameter portion which, on actuation of the expander plug into a second position, permits collapse of the centre mandrel by generally radially inward movement of the mandrel segments towards a position of engagement with the smaller-diameter portion of the expander plug, for removal of the transversely corrugated tubular member from the centre mandrel.

The invention also comprehends an energy-absorbing steering column for a motor vehicle, comprising a steering shaft which is collapsible axially in response to impact forces, and a transversely corrugated tubular member as aforesaid connected as a jacket tube for the collapsible steering shaft, such that energy of an impact is in effect absorbed by conversion into the deformation force required for axial collapse of the corrugations.

The appended claims define the scope of the invention claimed. The invention and how it can be performed are hereinafter particularly described with reference to the accompanying drawings, in which:

FIG. 1 is a fragmentary longitudinal section showing one embodiment of apparatus in accordance with the present invention for forming transverse corrugations in a tubular blank;

FIG. 2 is a plan view, with parts broken away, of a die assembly forming part of the apparatus shown in FIG. 1;

FIG. 3 is a local cross-section of a segmental centre mandrel forming part of the apparatus shown in FIG. 1; and

FIGS. 4a, 4b and 4c illustrate schematically three stages in the production of a corrugated tube using the apparatus of FIG. 1.

The apparatus shown in FIG. 1 of the drawings comprises an elongate segmental centre mandrel 10, and a die assembly 12 comprising a ring of eight toothed wheels 14 which are rotatably mounted in a common holder 16 (seen best in FIG. 2).

The centre mandrel 10 is formed externally with transverse corrugations 18 (circumferential corrugations) substantially corresponding to those to be formed in the tubular blank. The centre mandrel 10 has a circular cross-section, and is made up of eight like

segments 20 (shown in FIG. 3) surrounding an expander plug 22 which is slidably mounted in a mandrel support housing 24 by way of a guide bush 26. In a lower position of the expander plug 22, as shown in FIG. 1, a relatively large-diameter portion 28 of the expander plug holds the segments 20 of the centre mandrel 10 in their expanded, operative position (as is also illustrated in FIG. 3), with radially outward movement of the segments of the mandrel being limited by a circular spring retainer 30 accommodated in a circumferential groove at the lower end of the segments, and also by engagement of an external flange-like upper end portion 32 of the ring of segments with the wall of a locating groove 34 in the mandrel support housing 24.

Movement of the expander plug 22 upwardly to a withdrawn position in which a relatively small-diameter portion 36 of the expander plug is disposed within the segments 20 of the centre mandrel allows the mandrel to collapse by radially inward movement of the mandrel segments into engagement with the small-diameter portion 36 of the expander plug. Locating pins (not shown) project from the expander plug into the spaces between the mandrel segments to maintain the correct circumferential positioning of the mandrel segments.

The die assembly 12 including the ring of eight toothed wheels 14 rotatably mounted in the common holder 16 is disposed coaxially with respect to the longitudinal axis of the centre mandrel 10, with the toothed wheels 14 being arranged around the longitudinal axis of the centre mandrel in a symmetrical fashion, as is shown most clearly in FIG. 2, the arrangement being such that the toothed wheels are disposed in respective longitudinally extending radial planes of the longitudinal axis of the centre mandrel. The eight toothed wheels 14 are mounted on individual shafts 38 so as to be rotatable independently of one another, and correspondingly eight resilient detents in the form of spring-loaded ball plungers 40 are mounted in respective bores of the holder 16 and co-operate with adjacent teeth of the respective toothed wheels 14 to ensure correct initial positioning of all the toothed wheels, such as to maintain the teeth of each wheel initially in register with the teeth of all the other wheels.

As is shown in FIG. 2, the crests of the teeth of the toothed wheels 14 are concave between the tooth flanks, with the same curvature as the circular crests of the transverse corrugations of the centre mandrel, there being a slight chamfer at the tooth flanks to give a good fit at the circular throat formed by the ring of toothed wheels, with only a small gap between the teeth of adjacent wheels. The gaps between the teeth of the adjacent wheels 14 are radially aligned with the gaps between the segments 20 of the centre mandrel 10. The circular pitch of the teeth of the toothed wheels 14 is equal to the linear pitch of the transverse corrugations of the centre mandrel.

To produce a corrugated tubular blank for use as an energy-absorbing member in an energy-absorbing steering column for a motor vehicle, the procedure is as is illustrated in FIG. 4. Initially, a tubular blank 42 of appropriate length is parted off from steel tube stock, and the ends of the blank are de-burred. By the use of swaging dies, the end portions of the tubular blank are reduced in diameter to provide cylindrical portions to which bearings or tube extensions can subsequently be fitted, thereby also forming annular should-

ders between the respective reduced-diameter end portions and the full-diameter portion of the tubular blank.

The resulting pre-formed tubular blank (component tube) 44 is then formed with transverse corrugations on its full-diameter portion in the apparatus which has been described, to provide the required corrugated tubular member 46. For this purpose, the pre-formed tubular blank 44 is positioned around the external transversely corrugated portion 18 of the collapsed centre mandrel 10, with one of its shoulders abutted to the leading external transverse corrugation on the centre mandrel, and the centre mandrel is expanded, whereupon, by means of a press arrangement (not shown), relative axial displacement of the expanded centre mandrel and tubular blank, and the die assembly 12, is effected towards one another, specifically by displacing the die assembly upwardly along the centre mandrel.

By reason of the relative axial displacement, abutment of the full-diameter portion of the tubular blank with the circumferentially aligned teeth at the throat of the ring of toothed wheels constrains the toothed wheels to rotate in synchronism, with progressive formation of the required transverse corrugations in the tubular blank, as successive teeth of each of the wheels 14 index with successive corrugations 18 of the centre mandrel 10 with an action somewhat similar to that of a rack and pinion. The teeth of the rotating wheels will be seen from FIG. 1 to provide primarily a bending action at the "nip" between the teeth and the corrugations of the centre mandrel, and during the progressive formation of the transverse corrugations in the tubular blank the extra material required for forming the corrugations is allowed to flow in, over the corrugations of the centre mandrel, from the free upper end. Thereby, thinning of the tube wall by a drawing action may be kept to a very low value.

When the required number of corrugations has been formed along the full-diameter portion of the tubular blank, the die assembly is withdrawn to its original position, and the expander plug is withdrawn to allow the centre mandrel to collapse, whereupon the corrugated tube member can be removed from the centre mandrel.

The resulting corrugated tube member has longitudinal ribs corresponding to the gaps between the mandrel segments and between the toothed wheels, which is considered advantageous when the corrugated tube member is to be utilised as energy-absorbing member in an energy-absorbing steering column, since the longitudinal ribs increase the bending strength of the corrugated tube member, so increasing the likelihood of the corrugated tube member collapsing in straight-line fashion under impact conditions.

For some applications it may be desirable to vary the physical characteristics (primarily the strength) of the transverse corrugations in the corrugated tube members, either progressively or intermittently throughout the length of the corrugated portion of the tube member. This can be done by having the individual toothed wheels and their supporting shafts held in respective slide members which are mounted separately in a common holder, with actuation of the slide members in a generally radially inward direction (that is, towards the longitudinal axis of the centre mandrel) by means of an annular cam ring. The cam ring could for instance be actuated by a barrel-type cam, for variation in the form

of the successive corrugations to a predetermined pattern.

What is claimed is:

1. A method of forming transverse corrugations in a tubular blank, comprising positioning the blank on an externally transversely corrugated portion of an elongate segmental centre mandrel, the transverse corrugations on which substantially correspond to those to be formed in the tubular blank; effecting relative axial displacement of the centre mandrel and blank and a die assembly comprising a ring of toothed wheels which extend radially of the longitudinal axis of the centre mandrel and are rotatably mounted in a common holder with the axes of rotation of the toothed wheels disposed in a common radial plane of the longitudinal axis of the centre mandrel, the circular pitch of the teeth of each wheel being equal to the linear pitch of the corrugations of the centre mandrel, such that the relative axial displacement of the centre mandrel and the die assembly causes progressive formation of transverse corrugations in the interposed tubular blank as successive teeth of each of the wheels index with successive corrugations of the centre mandrel with a rack and pinion action; effecting collapse of the segmental centre mandrel and removing the resulting transversely corrugated tubular member from the collapsed centre mandrel.

2. A method of forming transverse corrugations in a tubular metal blank that includes a full-diameter generally cylindrical portion separated, towards at least one end of the blank, by an annular shoulder from a lesser-diameter generally cylindrical end portion, the method comprising positioning the blank coaxially on an externally transversely corrugated portion of an elongate centre mandrel, with the said annular shoulder in register with a leading external transverse corrugation on the centre mandrel, effecting relative axial displacement of the centre mandrel and blank and a die assembly comprising a ring of toothed wheels which extend radially of the longitudinal axis of the centre mandrel and are rotatably mounted in a common holder with their axes of rotation disposed in a common radial plane of said axis, the circular pitch of the teeth of each wheel being equal to the linear pitch of the corrugations of the centre mandrel, such that said relative axial displacement causes progressive formation of transverse corrugations in the interposed full-diameter portion of said tubular blank as successive teeth of each of the wheels index with successive corrugations of the centre mandrel with a rack and pinion action, with the extra material required for forming the corrugations in the blank being allowed to flow over the centre mandrel from the end of the blank opposite the end having said annular shoulder, whereafter collapse of the segmental centre mandrel is effected for removal of the resulting transversely corrugated tubular member therefrom.

3. Apparatus for forming transverse corrugations in a tubular blank, comprising an elongate segmental centre mandrel formed externally with transverse corrugations substantially corresponding to those to be formed in the tubular blank, a die assembly comprising a ring of toothed wheels which extend radially of the longitudinal axis of the centre mandrel and are rotatably mounted in a common holder with the axes of rotation of the toothed wheels disposed in a common radial plane of said axis, the circular pitch of the teeth of each wheel being equal to the linear pitch of the transverse corrugations of the centre mandrel, means for position-

ing all the toothed wheels in an initial position, means for effecting relative axial displacement of the centre mandrel and the die assembly whereby, with a tubular blank as aforesaid held in register with the centre mandrel around the transverse corrugations thereof, progressive formation of transverse corrugations in the interposed tubular blank is effected as successive teeth of each of the wheels index with successive corrugations of the centre mandrel with a rack and pinion action, and means actuable to permit collapse of said segmental centre mandrel for removal of the resulting transversely corrugated tubular member therefrom.

4. Apparatus for forming transverse corrugations in a tubular blank having a circular cross-section, comprising an elongate segmental centre mandrel which correspondingly has a circular cross-section and is formed externally with transverse corrugations substantially corresponding to those to be formed in the tubular blank, a die assembly comprising a ring of toothed wheels which extend radially of the longitudinal axis of the centre mandrel and are rotatably mounted in a common holder with the axes of rotation of the toothed wheels disposed in a common radial plane of said axis, the teeth of the toothed wheels having crests which are concave between the tooth flanks with a curvature which is the same as the curvature of the transverse corrugations of the centre mandrel, and the circular pitch of the teeth of each wheel being equal to the linear pitch of the transverse corrugations of the centre mandrel, spring-loaded ball detent arrangements mounted on the die assembly for co-operation with adjacent teeth of the respective toothed wheels for correct initial positioning of all the toothed wheels, means for effecting relative axial displacement of the centre mandrel and the die assembly whereby, with a tubular blank as aforesaid held in register with the centre mandrel around the transverse corrugations thereof, progressive formation of transverse corrugations in the interposed tubular blank is effected as successive teeth of each of the wheels index with successive corrugations of the centre mandrel with a rack and pinion action, and means actuable to permit collapse of said segmental centre mandrel for removal of the resulting transversely corrugated tubular member therefrom.

5. Apparatus for forming transverse corrugations in a tubular blank having a circular cross-section, comprising an elongate segmental centre mandrel which has a circular cross-section and is formed externally with transverse corrugations, a die assembly comprising a number of toothed wheels which is the same as the number of the segments of the centre mandrel, the toothed wheels extending radially of the longitudinal axis of the centre mandrel and being rotatably mounted in a common holder portion of the die assembly with the axes of rotation of the toothed wheels disposed in a common radial plane of said axis and with gaps between the inner peripheries of the toothed wheels being radially aligned with respective gaps between the individual segments of the centre mandrel, the teeth of the toothed wheels having crests which are concave between the tooth flanks with a curvature which is the same as the curvature of the transverse corrugations of

the centre mandrel, the circular pitch of the teeth of each wheel being equal to the linear pitch of the transverse corrugations of the centre mandrel, detent means for positioning all the toothed wheels in corresponding initial positions, means for effecting displacement of the die assembly relative to the centre mandrel, whereby, with a tubular blank as aforesaid in register with the centre mandrel around the transverse corrugations thereof, corresponding transverse corrugations are progressively formed in the successive parts of the tubular blank interposed between the toothed wheels of the die assembly and the centre mandrel, by the indexing of successive teeth of the wheels with successive corrugations of the centre mandrel with a rack and pinion action, and means selectively actuable to permit collapse of said segmental centre mandrel for removal of the resulting transversely corrugated tubular member from said mandrel.

6. Apparatus for forming transverse corrugations in a tubular blank having a circular cross-section, comprising an elongate centre mandrel which has a circular external cross-section and is made up of a plurality of circumferentially spaced elongate like segments, a mandrel support housing, an expander plug that is slidably mounted in a generally vertical position in the mandrel support housing and is surrounded by said mandrel segments, said expander plug including a full-diameter generally cylindrical portion which in a first position of the expander plug holds the segments of the centre mandrel in an expanded, operative position, with means being provided to limit radially outward movement of the segments of the centre mandrel, and said expander plug also including a smaller-diameter portion which, in response to actuation of means for moving said expander plug into a second position, permits collapse of the centre mandrel by generally radially inward movement of the mandrel segments towards a position of engagement with the smaller-diameter portion of the expander plug, the apparatus also comprising a die assembly having a ring of toothed wheels which extend radially of the longitudinal axis of the centre mandrel and are individually rotatably mounted in a common holder forming part of the die assembly with the axes of rotation of the toothed wheels disposed in a common radial plane of said axis, the circular pitch of the teeth of each wheel being equal to the linear pitch of the transverse corrugations of the centre mandrel, detent means for positioning all the toothed wheels in corresponding initial positions, means for effecting upward displacement of the die assembly with the centre mandrel maintained stationary by said mandrel support housing, whereby, with a tubular blank as aforesaid held in register with the centre mandrel, around the transverse corrugations thereof, transverse corrugations are progressively formed in the tubular blank as successive teeth of each of the toothed wheels index with successive corrugations of the centre mandrel with a rack and pinion action producing bending deformation of the interposed portion of the tubular blank for formation of said transverse corrugations in the tubular blank.

* * * * *