US 20090165518A1

(19) United States

(12) **Patent Application Publication** (10) **Pub. No.: US 2009/0165518 A1**

Booth (43) **Pub. Date: Jul. 2, 2009**

(54) **APPARATUS FOR AND METHOD OF MANUFACTURING HELICALLY WOUND STRUCTURES**

(76) Inventor: **John Peter Booth**, Yorkshire (GB)

Correspondence Address:
NIXON & VANDERHYE, PC
901 NORTH GLEBE ROAD, 11TH FLOOR
ARLINGTON, VA 22203 (US)

(21) Appl. No.: **12/086,982**

(22) PCT Filed: **Dec. 21, 2006**

(86) PCT No.: **PCT/GB2006/050471**

§ 371 (c)(1),
(2), (4) Date: **Jun. 23, 2008**

(30) **Foreign Application Priority Data**

Dec. 23, 2005 (GB) 0526409.8

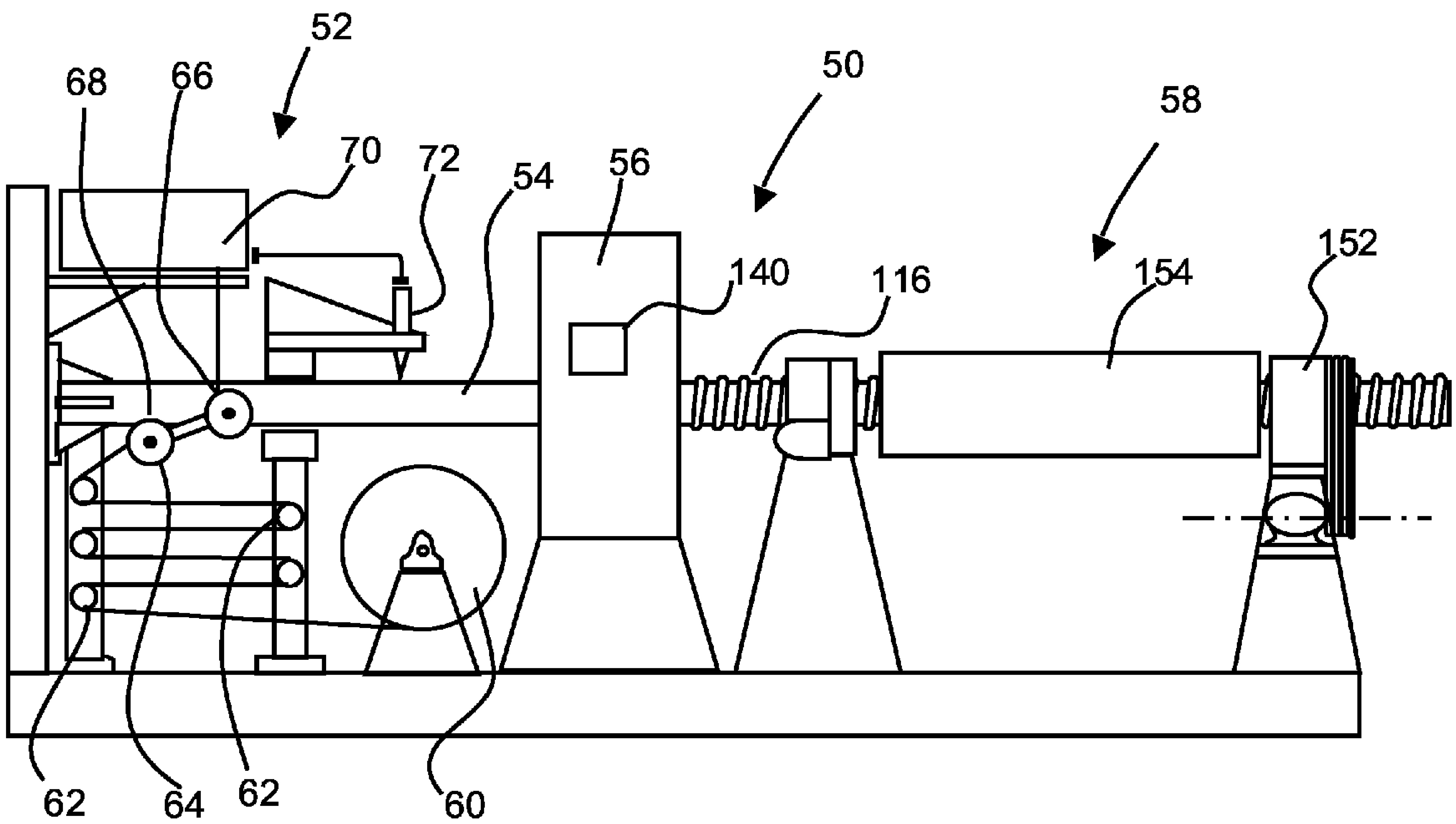
Publication Classification

(51) **Int. Cl.**
B21C 37/12 (2006.01)

(52) **U.S. Cl.** **72/50**; 156/466

(57) **ABSTRACT**

An apparatus (**50**) for and method of manufacturing helically wound tubular structures (**116**) includes a rotating faceplate (**74**) upon which are mounted a plurality of diameter defining rollers (**78**) which, in operation, cause a strip material (**80**) to be plastically deformed into a helical winding which may be lain down in abutting or self-overlapping relationship to form said tubular structure (**116**).



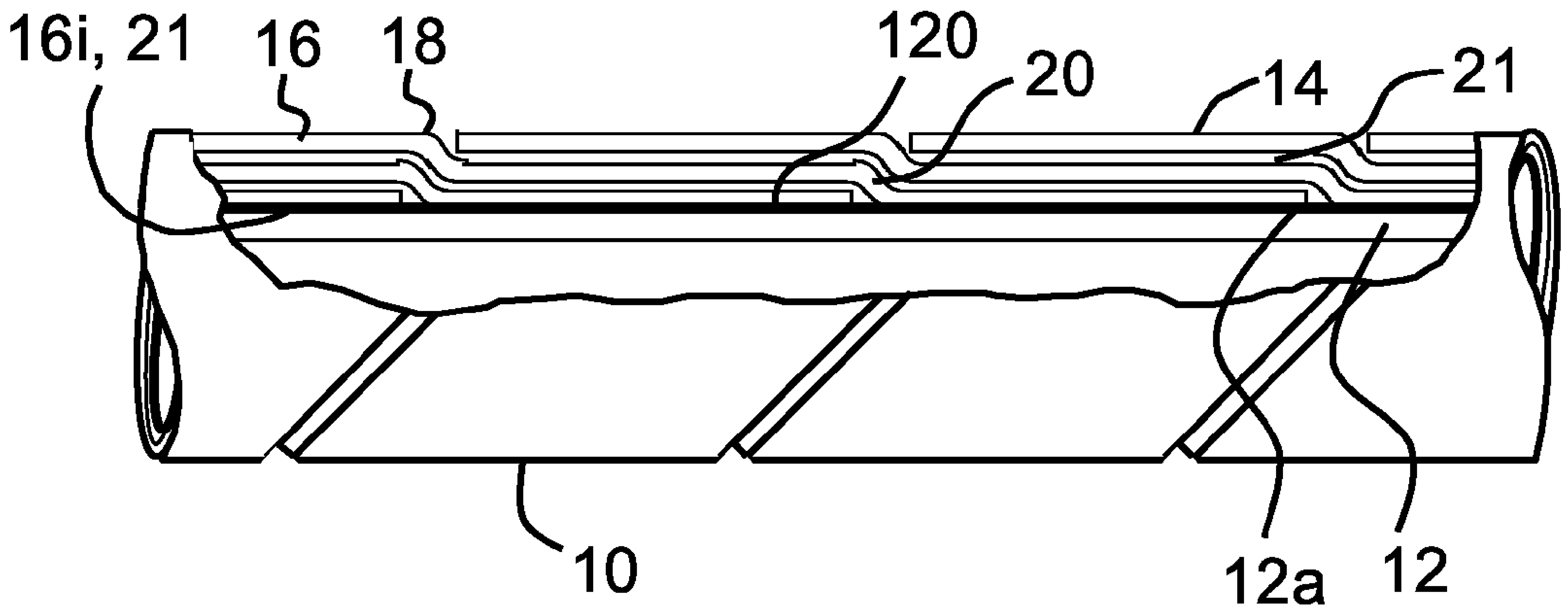

16i, 21
16
18
120
20
14
21
10
12a
12

Fig. 1

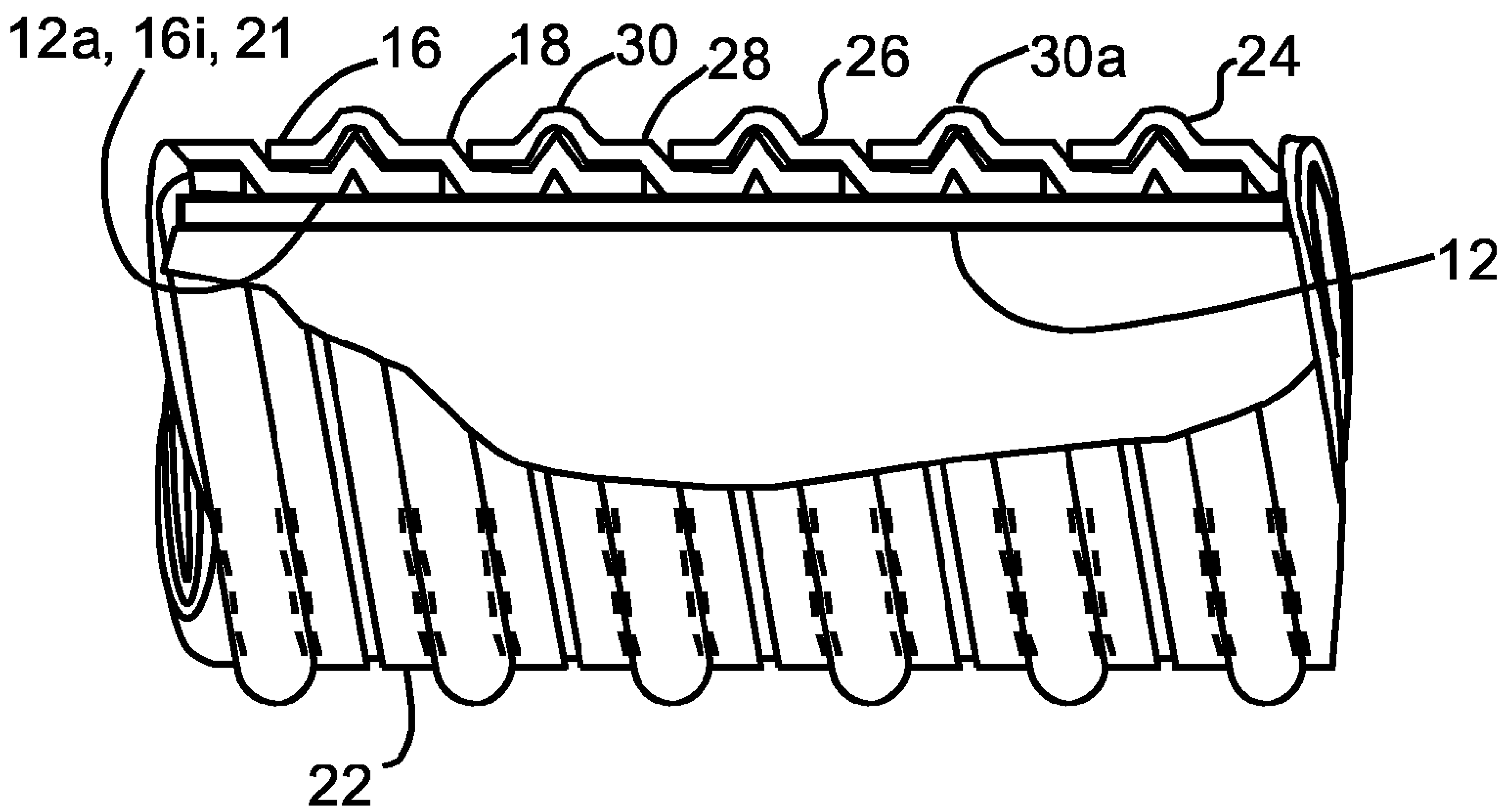

12a, 16i, 21
16
18
30
28
26
30a
24
12
22

Fig. 2

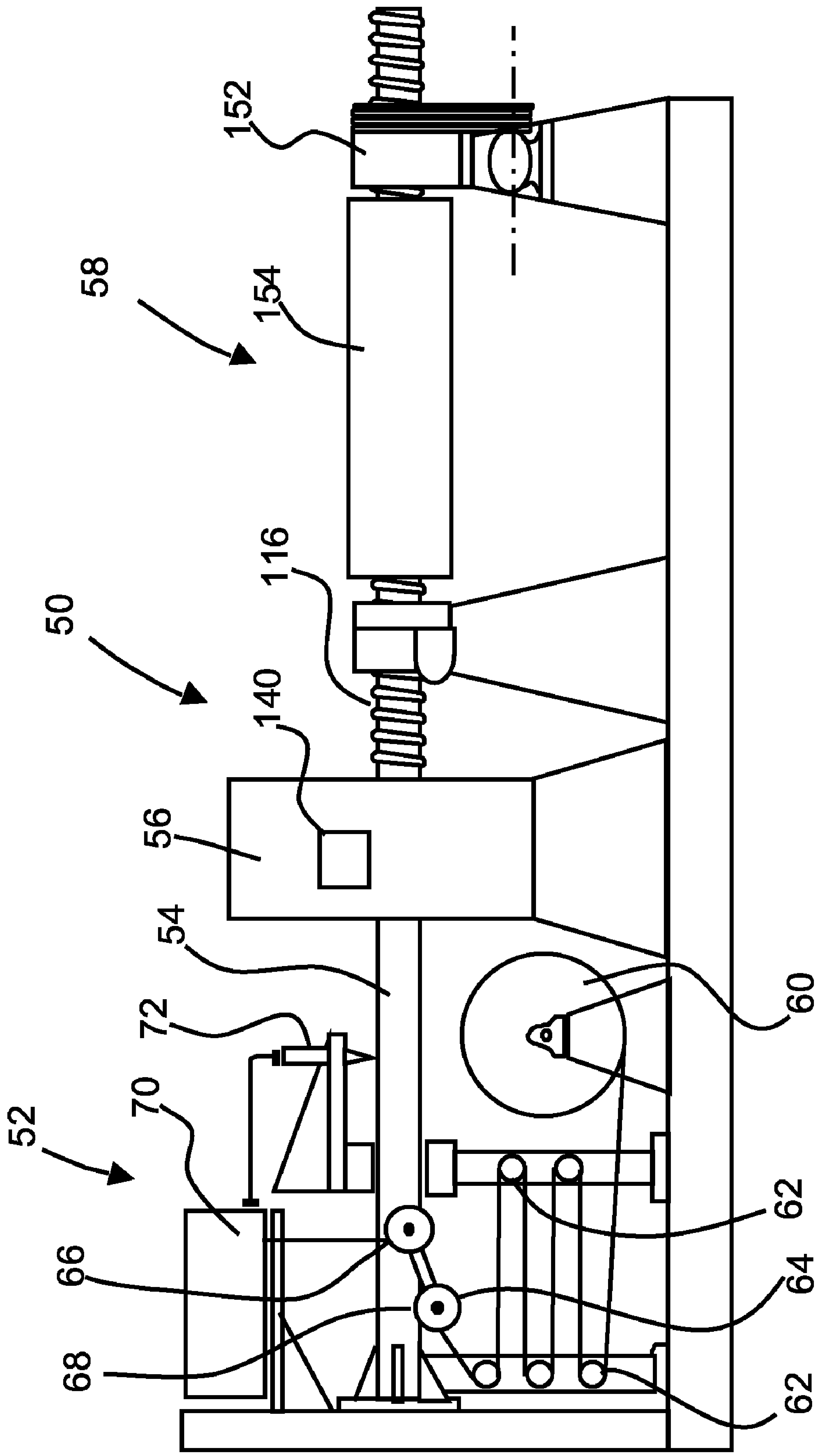


Fig. 3

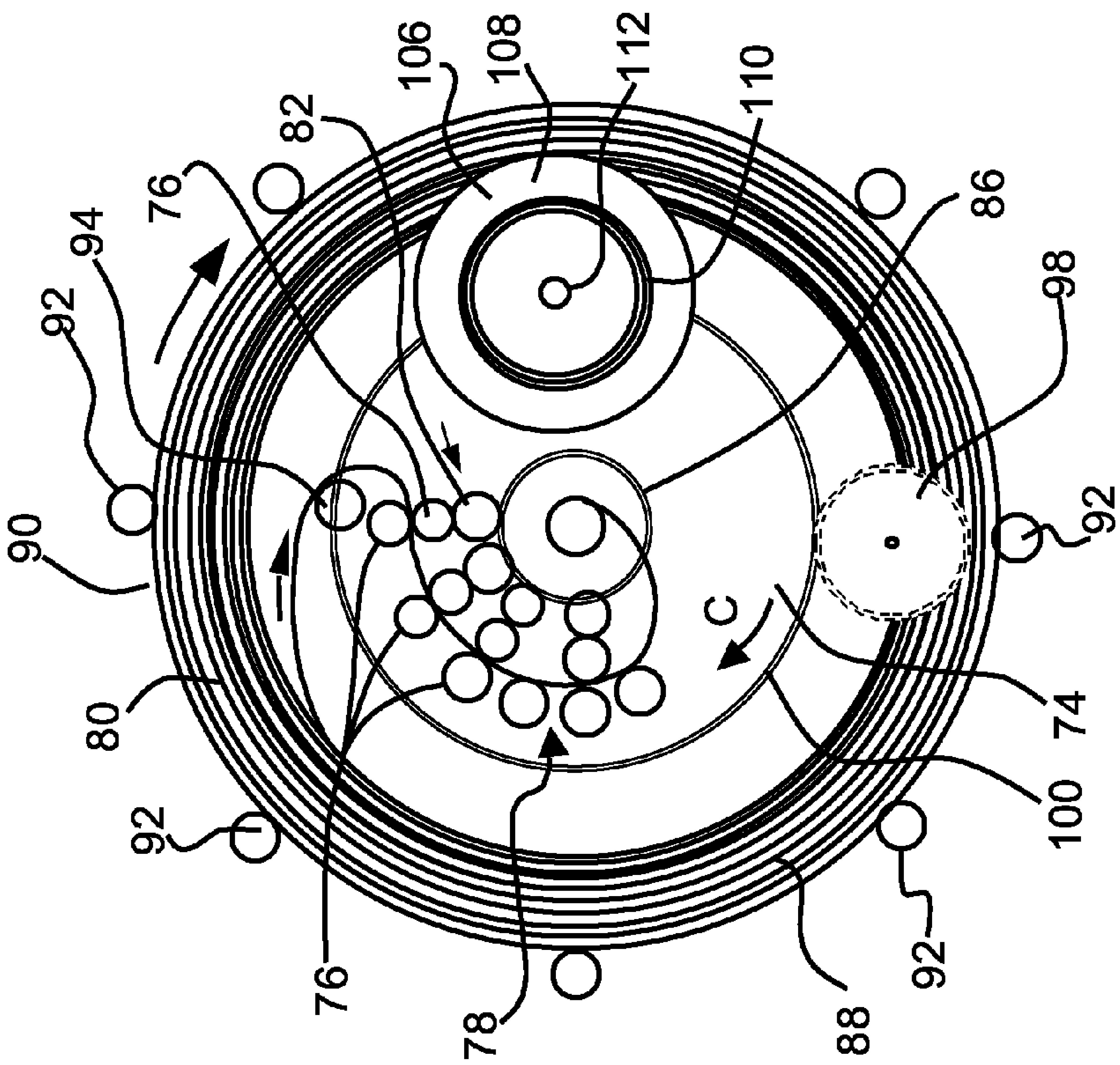

106
108
112
110
82
76
94
92
90
86
98
92
80
C
74
92
76
78
100
88
92

Fig. 5

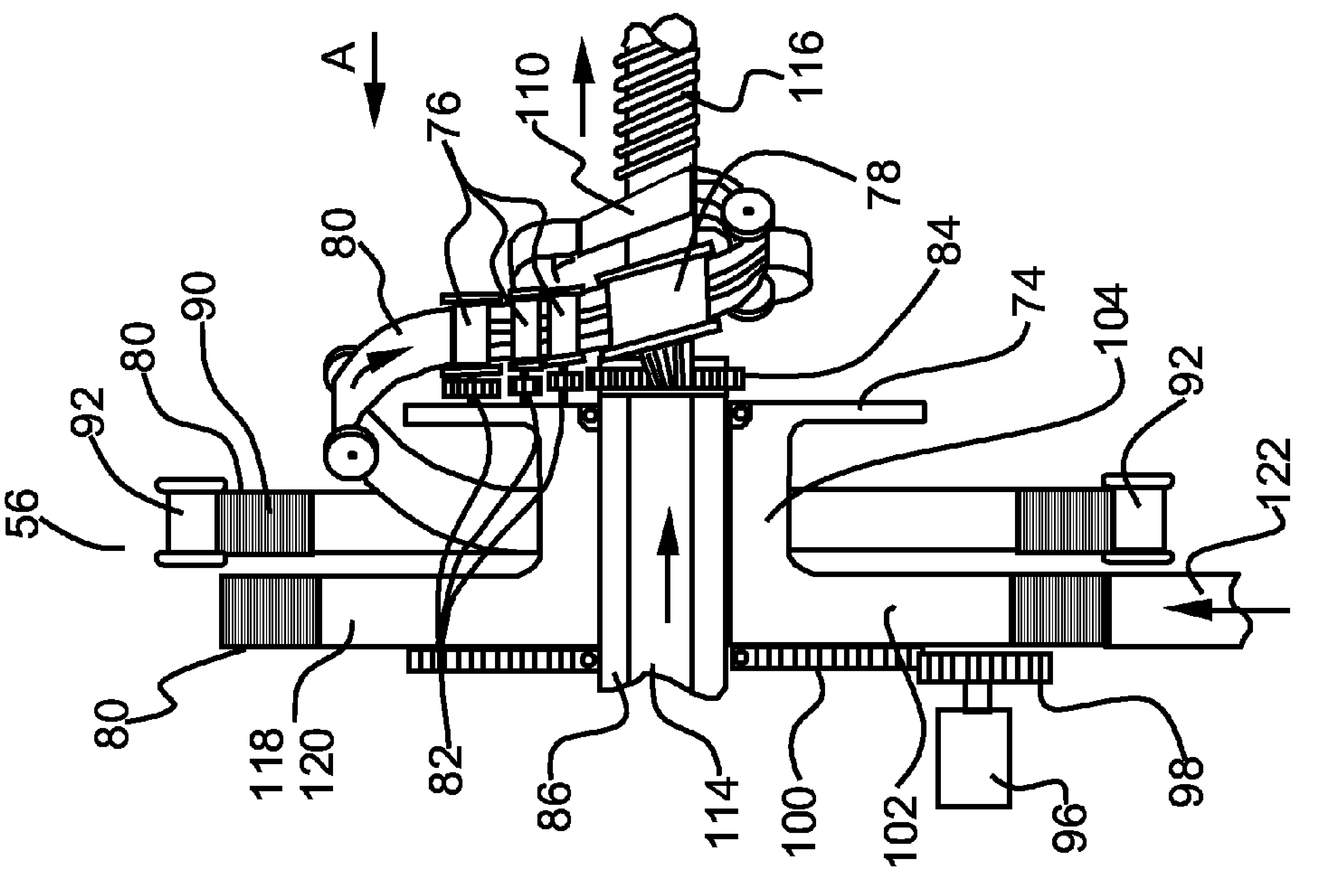

A
116
110
76
80
78
90
80
92
84
56
74
104
92
122
80
118
120
82
86
114
100
102
96
98

Fig. 4

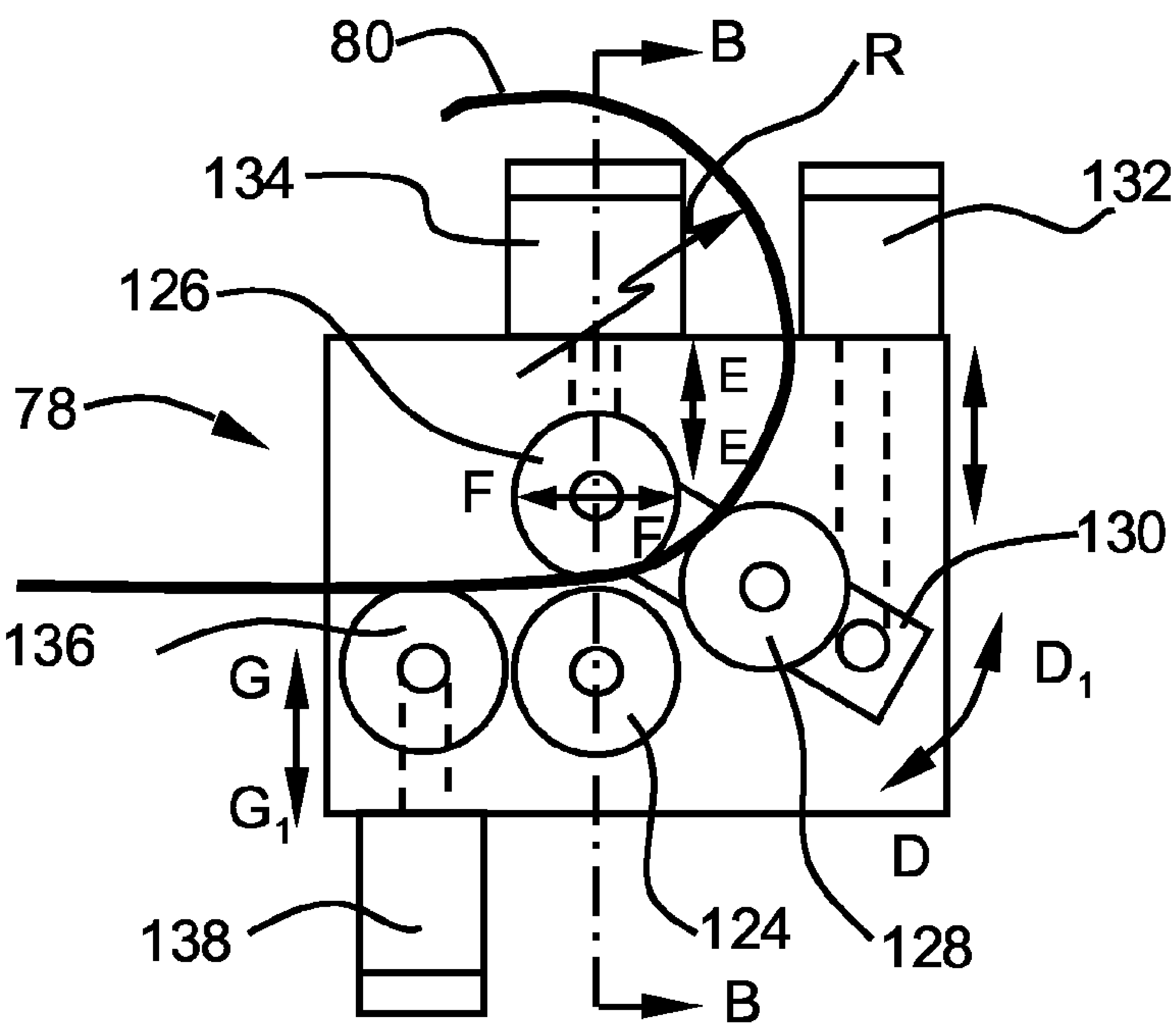

80
B
R
134
132
126
E
E
78
F
F
130
136
G
D1
G1
D
138
124
128
B

Fig. 6

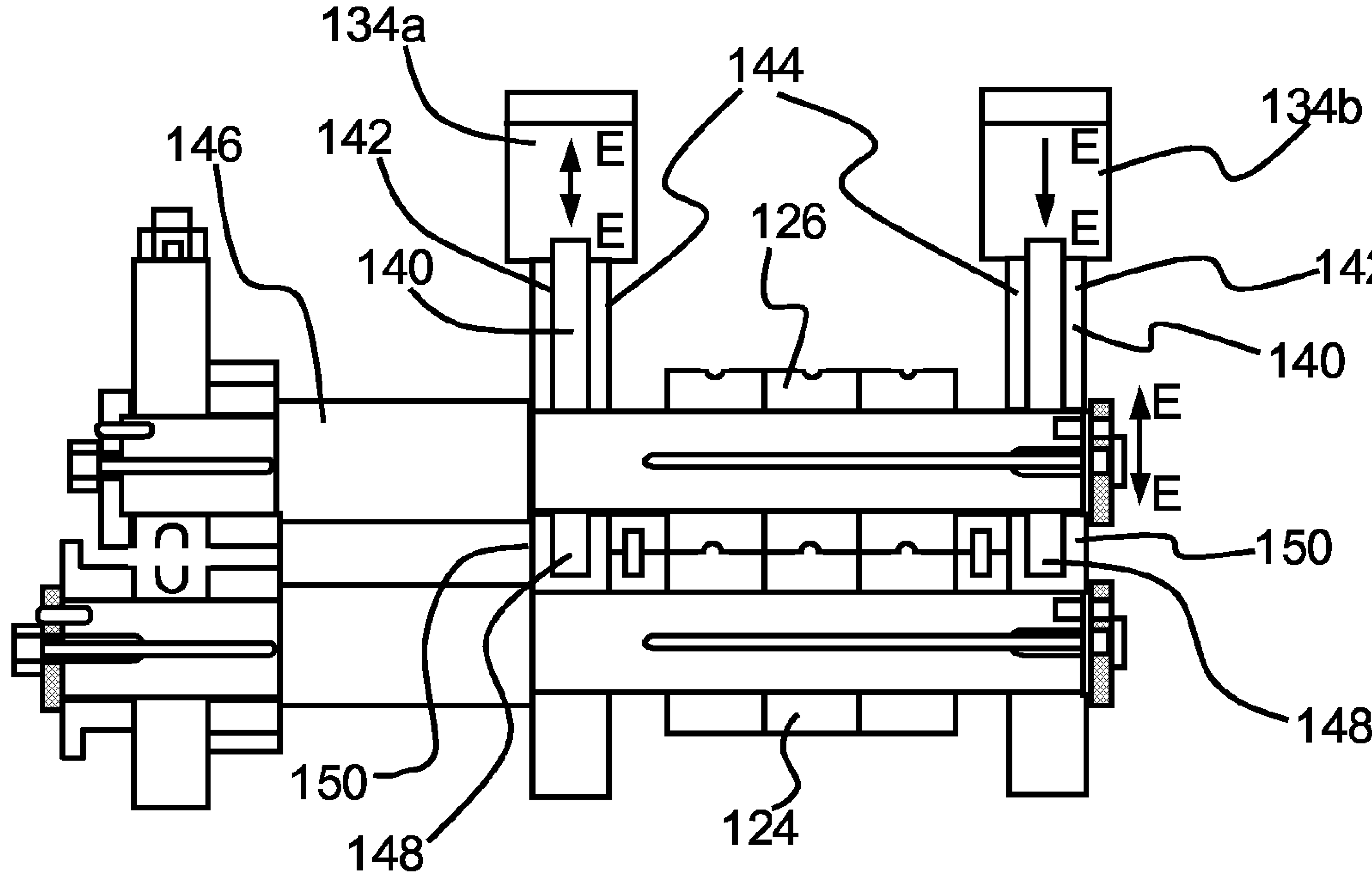

134a
144
134b
146
142
E
E
E
E
126
142
140
140
E
E
150
148
150
148
124

Fig. 7

APPARATUS FOR AND METHOD OF MANUFACTURING HELICALLY WOUND STRUCTURES

[0001] The present invention relates to an apparatus for and method of manufacturing helically wound structures and relates particularly to the manufacture of pipes and longitudinal structures formed by winding strips of metal in a helically overlapping relationship. Other structures such as storage vessels, towers and support structures may also benefit from features described herein.

[0002] Presently it is known to manufacture tubular structures by winding preformed metal strip onto a rotating mandrel such that the strip is deposited onto the mandrel in a self-overlapping manner and is retained in place by mechanical deformation of an edge thereof such that it interlocks with an adjacent edge, thereby to retain the strip in place on the final structure. EP0335969 discloses an apparatus for forming a helically wound tubular structure formed from a flat strip of metal wound onto a mandrel. The flat strip is fed from one or other of a pair of supply spools mounted concentrically with the axis of the tubular structure to be made. A rotating winding head is used to wind the strip onto the mandrel and includes a plurality of powered forming rollers which impart an initial form to the cross section of the metal strip before it is passed to a final set of rollers that lay the strip onto the mandrel and then swage over an edge of the strip so that it becomes mechanically locked to the previous layer over which it is wound. This is a complex process. Also provided is a mechanism for ensuring the strip supply is maintained constant and this mechanism includes speed control of the forming rollers. The coaxial supply bobbins are fed from an external supply spool so as to maintain the supply thereof. A welding station is used to join one end of the strip material to another without having to stop the machine.

[0003] It is also known to control the final diameter of the formed pipe by controlling a plurality of radius forming rollers immediately before the strip is wound into its final structure. Such an arrangement is disclosed in U.S. Pat. No. 3,851,376 which relates to a method and apparatus for forming a helical seam sealed metal pipe in which the spring back force of the material is controlled within permissible limits. A plurality of forming rollers are provided for this purpose and include a three roller arrangement of fixed rollers the position of which is selected and set to impart a desired radius of curvature to a metal strip as it passes through the rollers. An additional roller is displaceable in response to a feedback signal indicative of the spring back force so as to increase or decrease the forming force as necessary so as to ensure the spring back force is maintained within desired limits.

[0004] It is also known to elastically deform a metal strip and wind it into a self overlapping helically wound structure and employ an adhesive to maintain the strip in its final shape. Unfortunately, the strip retains its desire to return to its relaxed (flat) shape and the adhesive is necessary in order to prevent the strip delaminating and unwinding. Additionally, the final structure suffers from a high peel force created by the stresses within the plastically deformed strip and these put a great load on the adhesive itself, thereby compromising the structural integrity of the structure and limiting its pressure capacity significantly below its theoretical limit.

[0005] Whilst the above arrangements provide perfectly acceptable methods of manufacturing pipes they either rely on plastic deformation of an edge of the material strip to ensure the product stays together or must rotate the final product during the forming process, both of which can be problematic. For example, the force required to deform an edge of the metal strip as it is lain down onto a previously deposited layer and lock it thereto is significant. Additionally, such machines consume unnecessarily large amounts of energy and are very slow as operating such a deformation process at high speed is extremely difficult. The latter problem of having to rotate the product during forming limits the use of this arrangement to the production of relatively short sections of pipe and such sections must be joined if a long section is required. When laying trans-continental pipelines it is extremely undesirable to have to introduce any such joints as they tend to be expensive to incorporate and problematic in operation.

[0006] It is an object of the present invention to provide an apparatus for and method of manufacturing tubular structures which reduces and possibly overcomes some of the problems associated with the prior art.

[0007] Accordingly, the present invention provides an apparatus for manufacturing a tubular structure of helically wound strip comprising: a faceplate, mounted for rotation about a longitudinal axis; a drive mechanism, for driving the faceplate in a first direction about said longitudinal axis; and diameter defining rollers, mounted on said faceplate for causing the strip material to bend to a predetermined diameter prior to being formed into a tubular structure.

[0008] Preferably, the apparatus includes an assembly of shaping rollers, mounted for rotation with said faceplate and for forming a cross-sectional profile on strip material prior to it being formed to a pre-determined diameter. One or more of said shaping rollers may be driven rollers.

[0009] Preferably, the diameter defining rollers include three mutually confronting rollers, one of which is adjustable relative to the other two so as to cause any strip material passing between said rollers to adopt a radius of curvature defined by the positional relationship between said rollers.

[0010] In a particular arrangement the diameter defining rollers include a pair of pinch rollers rotatable about their own longitudinal axes and between which a strip of material may pass and a ring roller which is adjustable relative to a first pinch roller by rotation about the axis of the second.

[0011] In a most convenient arrangement the apparatus includes an actuator connected to said ring roller for effecting adjustment relative to said second pinch roller.

[0012] Advantageously, the apparatus may be provided with a reaction roller against which forming forces exerted on any strip as it is caused to adopt a radius of curvature by the ring roller will be reacted.

[0013] Preferably, the apparatus includes a second actuator for causing the axial position of the reaction roller to be varied relative to a pinch roller. An actuator may also be provided for effecting axial adjustment of one of said pinch rollers relative to the other.

[0014] Advantageously, the apparatus includes drive means for driving one or more of said diameter defining rollers.

[0015] In a particularly convenient arrangement the apparatus includes a computer coupled to said actuator or actuators for controlling the positional relationship of the roller or rollers. Said computer may comprise a computer programmed to control said roller or rollers in accordance with a predetermined programme.

[0016] Preferably, the apparatus includes a first gearing assembly mounted on said faceplate and driven from a fixed gear arranged coaxially with said faceplate and in which said first gearing assembly is engaged with said diameter defining rollers for driving said diameter defining rollers.

[0017] Conveniently, the apparatus further includes a second gearing assembly mounted on said faceplate and driven from a fixed gear arranged coaxially with said faceplate and In which said second gearing assembly is engaged with said forming rollers for driving said rollers. The apparatus may also include a main drive member for driving said faceplate in said first direction which may comprises a driven gear engaged with a corresponding gear portion on said faceplate.

[0018] Conveniently, the apparatus includes a stock support for supporting a supply of stock of strip material for being formed into a tubular structure. The stock support may comprise a circumferentially extending cassette extending around said faceplate on an outer diameter thereof.

[0019] Conveniently, said cassette comprises a plurality of support rollers circumferentially spaced around the longitudinal axis and which cooperate with a portion of a supply of strip stock and allow said stock to rotate about said axis. Said support rollers may be mounted for rotation about a spindle secured to a non rotating portion of said assembly.

[0020] In a particular arrangement the forming rollers are staggered along said longitudinal axis and in which the axis of rotation of said rollers relative to said axis varies in accordance the spiral angle of the trip as it passes from a supply thereof to said diameter defining rollers.

[0021] Conveniently, the apparatus may include a first strip supply guide roller for guiding a supply of strip material from a store thereof to said forming rollers. The apparatus may also include a second strip supply roller for guiding a supply of formed strip from said diameter defining rollers to an inner diameter at which a tubular member is to be formed.

[0022] Advantageously, the apparatus includes an adhesive applicator for applying an adhesive onto at least a portion of any strip after it passes through said diameter forming rollers. Said adhesive applicator may comprise an adhesive storing cassette for storing a roll of adhesive strip. Said adhesive storing cassette may include a spindle mounted on said faceplate for rotation therewith and around which a supply of adhesive strip may be positioned and rotate upon application of said adhesive strip to said tubular structure forming strip.

[0023] The apparatus may further include a backing removing mechanism for removing any protective backing on said adhesive strip prior to said adhesive strip being applied to the tubular structure forming strip.

[0024] Advantageously, the faceplate includes a central hole for receiving a core liner onto which said tubular forming strip may be wound to form a final tubular structure. Conveniently, there is provided a central support trunion having a hollow centre which defines said central hole for receiving said core liner.

[0025] Preferably, said support trunion is non rotating and includes a gear thereon which forms said fixed gear from which said rollers are driven.

[0026] Conveniently, said faceplate is mounted for rotation on said support trunion.

[0027] Advantageously, said faceplate includes a receiving station for receiving a supply of flat strip material to be formed into a tubular structure. Said receiving station may comprise a ring having a diameter corresponding to the diameter of the cassette, thereby to facilitate transfer of strip material therebetween upon depletion of material from said cassette.

[0028] Conveniently, the apparatus includes a supply means for supplying strip material to said receiving station as said station rotates, thereby to wind said strip material onto said receiving station in advance of material on said cassette being depleted.

[0029] According to a further aspect of the present invention there is provided a method of manufacturing a tubular structure comprising the steps of: bending a strip of material into a helical form by plastic deformation thereof; and winding said bent strip in a self overlapping manner into a tubular structure; wherein the strip is bent into said helical form with a radius of curvature less than the final radius of the structure to be formed.

[0030] Preferably, the method includes the step of passing said strip through a pair of pinch rollers and a ring roller adjustable relative to one of said pinch rollers such as to cause said strip to adopt said desired radius of curvature.

[0031] Advantageously, the method includes the step of passing the strip through a pair of pinched rollers, the axis of rotation of which are displaced relative to each other such as to cause said strip to adopt a bend along its length thereby to impart a sideways bend into said strip and create a strip having one edge longer than the other.

[0032] The method may include the step of applying an adhesive to portions of said strip which will be overlapping when formed into a tubular structure. Said adhesive may be applied by applying the adhesive as a strip of adhesive.

[0033] Advantageously, the method includes the step of protecting said strip of adhesive by applying a protective coating to at least one surface thereof and removing said protective coating prior to applying said adhesive onto said strip which forms said tubular structure.

[0034] Conveniently, the method includes the step of providing a tubular core and winding said strip onto said core so as to produce a tubular structure having an inner core and an outer casing of helically wound material. Preferably, the step of forming said tubular core is by roll forming a strip of material along its length and seam welding abutting longitudinal edges.

[0035] Alternatively, the method may include the step of forming said tubular core as a series of discrete lengths of tube and assembling them into a continuous or near continuous length prior to winding said strip material onto said core. Alternatively said tubular core may be provided as a length of extruded pipe of a plastics material.

[0036] In one arrangement said discrete lengths of tube are of a ceramics material.

[0037] The present Invention will now be more particularly described by way of example only with reference to the accompanying drawings in which:

[0038] FIGS. **1** and **2** are partial cross-sectional views of two types of tubular structure that may be formed by the apparatus described herein;

[0039] FIG. **3** is a schematic side elevation of an apparatus according to aspects of the present invention;

[0040] FIG. **4** is a side elevation of the forming head shown schematically in FIG. **3**

[0041] FIG. **5** is a front view of the forming head taken in the direction of arrow A in FIG. **4**;

[0042] FIG. **6** is a detailed view of the diameter forming roller arrangement shown generally in FIGS. **4** and **5**; and

[0043] FIG. **7** is a cross-sectional view of the pinch rollers taken in the direction of arrows B-B in FIG. **6**.

[0044] Referring now to FIG. **1** of the drawings, a tubular body indicated generally at **10** forms a pipe for use in a pipe system such as a pipeline carrying hot fluids (which may also be under pressure). The tubular body comprises an inner portion in the form of an inner hollow core **12** which may be formed by any one of a number of forming processes, as discussed above and an outer load carrying casing discussed in detail later herein. In the preferred process the inner pipe comprises a continuously formed core, as will also be discussed in detail later herein however, one may have a core made from a plurality of discrete lengths inter-engaged with each other so as to form a long length. The outer casing indicated generally at **14** is formed on the inner hollow core **12** by helically winding a strip **16** of material onto the outer surface **12***a* of the core **12** in self-overlapping fashion similar to the manner which is described in detail for the formation of a pipe on a mandrel in the specific descriptions of the applicants U.K. Patent No. 2,280,889 and U.S. Pat. No. 5,837,083. In accordance with one aspect of the present invention the strip may be wound under tension. The strips **16** which form the outer casing may have one or more transverse cross-sectional steps **18** and **20** each of which is preferably of a depth corresponding to the thickness of the strip **16**. The steps **18**, **20** are preferably preformed within the strip **16**, each extending from one end of the strip **16** to the other to facilitate an over-lapping centreless winding operation in which each convolution of the strip accommodates the overlapping portion of the next convolution. Whilst the strip may comprise any one of a number of materials such as a plastic, a composite material or indeed metal, it has been found that metal is particularly suitable in view of its generally high strength capability and ease of forming and joining as will be described later herein. Examples of suitable metals include steel, stainless steel, titanium and aluminium, some of which are particularly suitable due to their anti-corrosion capabilities. The internal surface **16***i* of the strip **16** and the outer surface of the pipe **12***o* may be secured together by a structural adhesive, as may the overlapping portions **16***a* of the strip. The use of an adhesive helps ensure that all individual components of the tubular member **10** strain at a similar rate. The application of the adhesive may be by any one of a number of means but one particularly suitable arrangement is discussed in detail later herein together with a number of other options.

[0045] Referring now more particularly to FIG. **3**, from which it will be seen that an apparatus **50** for manufacturing helically wound structures comprises: an optional pre-forming portion **52**, in which a core **54** is formed; a forming station, shown schematically at **56** and described in detail later herein; and a post forming section, shown generally at **58** and including a number of optional features discussed later. In one arrangement of the optional pre-forming portion **52** there is provided a store of flat strip material in the form of a roll of metal strip **60** and a plurality of feed rollers **62** which feed the strip to forming rollers **64** and **66** which in turn roll the edges of the strip together around a central mandrel **68** so as to form a tubular structure **54** having confronting edges abutting each other (not shown). A welding apparatus shown generally at **70** and including a welding head **72** is used to weld together the confronting edges in a manner well known in the art and therefore not described further herein. An alternative core forming process might comprise the manufacture of a plurality of discrete lengths of tubular structure, each of which are provided with inter-engaging features on confronting ends thereof such as to allow a plurality of said lengths to be assembled into a long section of core. When employing such a core arrangement one may replace the strip forming and welding arrangement with a suitable feed mechanism (not shown) for feeding a plurality of said discrete lengths into the forming station in a continuous manner. Once formed, the core of whatever description is fed into the forming station **56**, which is best seen with reference to FIGS. **4** and **5**.

[0046] Referring to the drawings in general but particularly FIG. **4** which is a side elevation of the forming station **56** and comprises a faceplate **74** upon which are mounted a plurality of shaping rollers **76** and a set of diameter defining rollers, shown generally at **78**. As shown, the shaping rollers are profiled so as to form a cross-sectional form to the strip as best seen in FIGS. **1** or **2**. It will, however, be appreciated that the forming rollers could impart an alternative form to the strip or may, in some circumstances, be eliminated all together. When provided, the shaping rollers are best provided as a plurality of confronting rollers (best seen in FIG. **5**) between which the strip **80** is sandwiched as it passes therebetween so as to impart the desired profile into the strip in a progressive manner, with each pair of rollers increasing the deformation of the strip until the final desired profile is formed. As shown, the shaping rollers are each driven by means of a drive gear **82** each of which is mounted for rotation about an axis on said faceplate and engages on one side with a shaping roller and on another side with a sun gear **84** formed on a non rotating portion **86**, which is described in detail later herein. As the faceplate **74** rotates in the direction of arrow C (FIG. **5**) gears **76** and **82** rotate therewith but as they are coupled to the sun gear **84** they are caused to rotate about their axes and drive the strip through the pinch formed between confronting shaping rollers **76**. As shown, the shaping rollers are each slightly staggered along longitudinal axis X and the axis of rotation of each roller varies in accordance with the spiral angle as the strip **80** passes from the supply thereof to the diameter defining rollers **78**. It will, however, be appreciated that a simpler non staggered arrangement may be used where there is sufficient room to shape the strip and then position it correctly before applying it to the radius forming rollers **78**. In order to ensure an even feed of strip material form a supply thereof it may be desirable to provide a supply thereof in the form of stock supply **88**. Advantageously this stock supply may be provided in a cassette or stock support **90** comprising a plurality of support rollers **92** positioned outside of said forming station and being circumferentially spaced around longitudinal axis X. Said support rollers **92** cooperate with a portion of the stock of strip material **88** and allows the stock to rotate about axis X. The strip material **80** is removed from an inner diameter of said stock thereof and fed via a first strip supply guide roller **94** mounted for rotation on said faceplate **74** about an axis substantially perpendicular thereto. In order to drive the faceplate **74** one may provide a motor **96** and gear drive **98** coupled to a ring gear **100** provided on a back plate **102** which is directly linked to face plate via annular portion **104** through which non rotating portion **86** extends.

[0047] Also shown in FIGS. **4** and **5** is the diameter defining roller arrangement seen generally at **78** and which between them act to curve the strip material by plastically deforming it around one of the rollers such as to define the diameter of the exiting strip. This arrangement is best seen with reference to FIGS. **6** and **7** and is described in detail later herein. An optional adhesive applicator **106** may also be mounted on the faceplate **74** for rotation therewith. The applicator may take a number of forms for supplying adhesive to the strip after it has been formed and one particular arrangement is shown in which a storage cassette **108** is provided with a roll of adhesive strip **110**. The storage cassette **108** is mounted for rotation about a spindle **112** mounted on the faceplate for rotation therewith such that upon rotation of the faceplate adhesive strip may be dispensed onto the surface of the strip **80** as it is lain down onto the core **54** (FIG. **3**). The strip of adhesive may be provided in the form of a strip having a backing and this backing may be removed by backing removing means (not shown) prior to said adhesive being applied. It will be appreciated from the cross-sectional view of FIG. **4** that the faceplate **74** includes a central hole **114** for receiving a core or liner **54** onto which said strip material **80** may be wound so as to form a final structure **116**. The central hole may be provided with a central support trunion **86** having a hollow centre which defines said central apperture **114** for receiving said core or liner **54**. When provided, the trunion may be mounted within said central hole **114** by means of bearings **116**, such that said faceplate **74** can rotate about said trunion **86**. Also shown in FIG. **4** is a receiving station **118** in the form of ring **120** having a diameter corresponding to the diameter of the cassette thereby to facilitate the transfer of strip material therebetween upon depletion of the material on the cassette. A supply of strip material **122** forms a supply means for supplying strip material to said receiving station as said station rotates, thereby to wind said strip onto said supply station at the same rate as it is depleted form said cassette.

[0048] Turning now to FIGS. **6** and **7** which illustrate in more detail the format of the diameter forming rollers **78**, it will be seen that the rollers include a pair of pinch rollers **124**,**126** and a ring roller **128** mounted on a pivot arm **130** pivotable about the axis of rotation of one of the pinch rollers. It matters not which roller axis the pivot arm rotates. An actuator shown schematically at **132** is connected to the pivot arm **130** so as to initiate and control pivoting rotation of said ring roller in the direction of arrows D-D in accordance with desired control parameters discussed later herein. A further actuator **134** is provided to alter the position of one of the pinch rollers **126** relative to the other **124** in the directions of arrows E-E and F-F, again as discussed in detail later herein. A final reaction roller **136** is provided in order to react any forces experienced by the bending of the strip as it passes between the pinch rollers and the ring roller **124**, **126** and **128** respectively. This reaction roller may also be controllable by actuator **138** so as to move it into or away from the strip **80** in the direction of arrows G-G as required. FIG. **7** illustrates by way of a cross-sectional drawing the actuator and roller control system in more detail. From this drawing it will be appreciated that actuator **134** is preferably provided as a matched pair, one at each end of roller **126** so as to allow differential and equal alteration of the axial position of roller **126**. In this particular arrangement the actuator spindle **140** passes from the grounded actuator and through a hole **142** passing through an upper block portion **144**, past roller spindle **46** (displaced relative thereto) and into lower block portion **146** into which it is anchored at **148**. A small gap **150** provided between the blocks such that displacement of spindle **140** will cause roller **126** to move closer to or away from roller **124** in accordance with the actuator control parameters. Referring now more particularly to drawings **6** and **7** collectively we will describe the control principles. As mentioned above, roller **126** is adjustable in the directions of arrows E-E and F-F by means of independently or collectively controlled actuators **134***a*, **134***b*. Roller **128** is movable in the direction of arrows D-D_1 by actuator **132** and roller **136** is movable in the direction of arrows G-G, by actuator **138**. Each actuator is connected to and controlled by means of computer **140** (FIG. **3**). In order to create the desired radius of curvature R on the strip **80** before it is lain down to form a tubular structure one simply needs to set and possibly adjust the position of roller **128** such that it causes the strip **80** to be bent about the axis of roller **126** and plastically deformed such that the desired degree of final bending is achieved after any spring-back effect. To set and adjust the degree of pinch that the strip experiences as it passes through pinch rollers **124**, **126** one simply adjusts the axial position of roller **126** relative to roller **124**. This adjustment can be a collective adjustment or a differential adjustment. Differential adjustment will cause one side of the strip to be pinched more than the other and if plastic deformation is induced this will cause one side of the strip to adopt a length slightly longer than the other. This arrangement helps the strip sit comfortably as it is lain down on the previously deposited layer of a multi-layer product. It will be appreciated that the longer edge is the edge that is first deposited down as this will be the edge that lies at the greater diameter and must fit to the diameter of the layer underneath it. As an alternative to differential movement In the direction of arrows E-E one might move roller **126** differentially in the direction of arrows F-F which will have a similar affect on the differential thickness. Should it be necessary to increase or alter the degree of bending the strip is subjected to then it may be necessary to adjust the axial position of roller **136** by actuating actuator **138** and move roller **136** appropriately.

[0049] Referring now once again to FIG. **3**, an optional post forming section **58** may include such things as an optional drive mechanism **152** and adhesive curing heater **154**.

[0050] Referring to the drawings in general, it will be appreciated that a tubular structure may be manufactured by causing the faceplate **74** to rotate. This action in turn will cause the strip material **80** to be drawn from the cassette, passed through shaping rollers **76** and into diameter defining rollers **78** at which point the desired diameter is formed by appropriate positional control of rollers **124**, **126** and **128**. As the strip exits the diameter defining rollers it is directed towards the core **54** and wrapped therearound in a self overlapping arrangement best appreciated with reference to FIGS. **1** and **2**. Before the strip is finally deposited onto the core it may be supplemented by an adhesive dispensed as a strip thereof form dispenser **106**. Continuous rotation of faceplate **74** will cause continuous deformation and deposition of the strip **80** and this process will continue so long as there is a supply of strip material within the cassette store. Once the strip material has been depleted it is necessary to transfer the secondary supply from station **118** across to the cassette and weld one end to the other before recommencing operations. It will also be appreciated that some forms of structure need not have a core and the above process may be undertaken without a core being supplied to the faceplate. In such an arrangement it may be necessary to provide a support to the initial portion of tubular structure formed but once an initial portion has been formed the structure will be self supporting as new layers are effectively deposited down on a stable multi layer structure. Indeed, one may well adopt such an arrangement when it is desirable to form a tapered structure for which one would find it difficult to produce a tapered inner core. Structures without cores are, therefore, within the scope of the present invention. In the production of such a tapered structure it is simply necessary to vary the degree of bending applied to the strip and this can be done by applying a variable force position to ring roller **128** so as to change the rolling radius as required. This process may be controlled by the computer **140** in accordance with a predetermined control methodology.

[0051] Additional features of this machine include feedback control from the computer to ensure the product diameter is maintained within desired limits and/or altered according to desired parameters. It will be appreciated that as one can control the degree of plastic deformation of the strip as it passes through the radius forming rollers one can also control the final diameter of any tubular structure formed by this apparatus. One important feature of this machine is its ability to form the radius of curvature R such that it is slightly less than that of the core onto which it is to be wound. Such an arrangement has a significant affect on the final product as a strip so formed (to a smaller than required radius) as the outer helically wound strip will effectively grip the previous layer or the core and ensure close contact therebetween and thus provide a better mechanical joint therebetween than might be possible without this feature. Additionally, by plastically deforming the strip rather than elastically deforming the strip as is known in the art one will be placing any adhesive used under far less or possibly no peel loading at all, thus helping to maintain the integrity of the final structure and increasing its pressure capacity closer to its theoretical maximum.

[0052] It will also be appreciated that the above described method and apparatus may be used to cover an already existing pipeline with an outer casing. In this arrangement the already existing pipeline forms a core and the machine simply rotates around the core and moves therealong so as to lay down the outer wrap of strip material onto the pipeline. Such an approach could be employed when one wishes to repair or strengthen an already existing pipeline.

1. An apparatus for manufacturing a tubular structure of helically wound strip comprising:

a faceplate, mounted for rotation about a longitudinal axis;

a drive mechanism, for driving the faceplate in a first direction about said longitudinal axis; and

diameter defining rollers, mounted on said faceplate for causing the strip material to bend to a predetermined diameter prior to being formed into a tubular structure.

2. An apparatus as claimed in claim **1** including an assembly of shaping rollers, mounted for rotation with said faceplate and for forming a cross-sectional profile on strip material prior to it being formed to a pre-determined diameter.

3. An apparatus as claimed in claim **1** in which one or more of said shaping rollers are driven rollers.

4. An apparatus as claimed in claim **2** in which the diameter defining rollers include three mutually confronting rollers, one of which is adjustable relative to the other two so as to cause any strip material passing between said rollers to adopt a radius of curvature defined by the positional relationship between said rollers.

5. An apparatus as claimed in claim **1** in which said diameter defining rollers include a pair of pinch rollers rotatable about their own longitudinal axes and between which a strip of material may pass and a ring roller which is adjustable relative to a first pinch roller by rotation about the axis of the second.

6. An apparatus as claimed in claim **5** and including an actuator connected to said ring roller for effecting adjustment relative to said second pinch roller.

7. An apparatus as claimed in claim **1** including a reaction roller against which forming forces exerted on any strip as it is caused to adopt a radius of curvature by the ring roller will be reacted.

8. An apparatus as claimed in claim **7** and including a second actuator for causing the axial position of the reaction roller to be varied relative to a pinch roller.

9. An apparatus as claimed in claim **1** in including an actuator for effecting axial adjustment of one of said pinch rollers relative to the other.

10. An apparatus as claimed in claim **1** including drive means for driving one or more of said diameter defining rollers.

11. An apparatus as claimed in claim **5** including an actuator connected to said ring roller for effecting adjustment relative to said second pinch roller and including a computer coupled to said actuator or actuators for controlling the positional relationship of the roller or rollers.

12. An apparatus as claimed in claim **5** including an actuator connected to said ring roller for effecting adjustment relative to said second pinch roller and including an actuator connected to said ring roller for effecting adjustment relative to said second pinch roller and further including a computer coupled to said actuator or actuators for controlling the positional relationship of the roller or rollers further in which said computer comprises a computer programmed to control said roller or rollers in accordance with a predetermined programme.

13. An apparatus as claimed in claim **1** and including a first gearing assembly mounted on said faceplate and driven from a fixed gear arranged coaxially with said faceplate and in which said first gearing assembly is engaged with said diameter defining rollers for driving said diameter defining rollers.

14. An apparatus as claimed in claim **13** and further including a second gearing assembly mounted on said faceplate and driven from a fixed gear arranged coaxially with said faceplate and in which said second gearing assembly is engaged with said forming rollers for driving said rollers

15. An apparatus as claimed in claim **1** and including a main drive member for driving said faceplate in said first direction.

16. An apparatus as claimed in claim **15** in which said main drive member comprises a driven gear engaged with a corresponding gear portion on said faceplate.

17. An apparatus as claimed in claim **1** and further including a stock support for supporting a supply of stock of strip material for being formed into a tubular structure.

18. An apparatus as claimed in claim **17** in which said stock support comprises a circumferentially extending cassette extending around said faceplate on an outer diameter thereof.

19. An apparatus as claimed in claim **17** in which said stock support comprises a circumferentially extending cassette extending around said faceplate on an outer diameter thereof and in which said cassette comprises a plurality of support rollers circumferentially spaced around the longitudinal axis and which cooperate with a portion of a supply of strip stock and allow said stock to rotate about said axis.

20. An apparatus as claimed in claim **17** in which said stock support comprises a circumferentially extending cassette extending around said faceplate on an outer diameter thereof, in which said cassette comprises a plurality of support rollers circumferentially spaced around the longitudinal axis and which cooperate with a portion of a supply of strip stock and allow said stock to rotate about said axis in which said support rollers are mounted for rotation about a spindle secured to a non rotating portion of said assembly.

21. An apparatus as claimed in claim **1** in which the forming rollers are staggered along said longitudinal axis and in which the axis of rotation of said rollers relative to said axis varies in accordance with the spiral angle of the strip as it passes from a supply thereof to said diameter defining rollers.

22. An apparatus as claimed in claim **1** including a first strip supply guide roller for guiding a supply of strip material from a store thereof to said forming rollers.

23. An apparatus as claimed in claim **1** including a second strip supply roller for guiding a supply of formed strip from said diameter defining rollers to an inner diameter at which a tubular member is to be formed.

24. An apparatus as claimed in claim **1** including an adhesive applicator for applying an adhesive onto at least a portion of any strip after it passes through said diameter forming rollers.

25. An apparatus as claimed in claim **24** in which said adhesive applicator comprises an adhesive storing cassette for storing a roll of adhesive strip.

26. An apparatus as claimed in claim **24** in which said adhesive applicator comprises an adhesive storing cassette for storing a roll of adhesive strip and in which said adhesive storing cassette includes a spindle mounted on said faceplate for rotation therewith and around which a supply of adhesive strip may be positioned and rotate upon application of said adhesive strip to said tubular structure forming strip.

27. An apparatus as claimed in claim **24** in which said adhesive applicator comprises an adhesive storing cassette for storing a roll of adhesive strip and the apparatus further comprises a backing removing mechanism for removing any protective backing on said adhesive strip prior to said adhesive strip being applied to the tubular structure forming strip.

28. An apparatus as claimed in claim **1** in which the faceplate includes a central hole for receiving a core liner onto which said tubular forming strip may be wound to form a final tubular structure.

29. An apparatus as claimed in claim **28** including a central support trunion having a hollow centre which defines said central hole for receiving said core liner.

30. An apparatus as claimed in claim **28** including a central support trunion having a hollow centre which defines said central hole for receiving said core liner and in which said support trunion is non rotating and includes a gear thereon which forms said fixed gear from which said rollers are driven.

31. An apparatus as claimed in claim **28** in which said apparatus includes a support trunion and said faceplate is mounted for rotation on the said support trunion.

32. An apparatus as claimed in claim **1** in which said faceplate includes a receiving station for receiving a supply of flat strip material to be formed into a tubular structure.

33. An apparatus as claimed in claim **32** in which said receiving station comprises a ring having a diameter corresponding to the diameter of the cassette, thereby to facilitate transfer of strip material therebetween upon depletion of material from said cassette.

34. An apparatus as claimed in claim **32** and including supply means for supplying strip material to said receiving station as said station rotates, thereby to wind said strip material onto said receiving station in advance of material on said cassette being depleted.

35. (canceled)

36. A tubular structure made on an apparatus as claimed in claim **1**.

37. A method of manufacturing a tubular structure comprising the steps of:

bending a strip of material into a helical form by plastic deformation thereof; and winding said bent strip in a self overlapping manner into a tubular structure; wherein the strip is bent into said helical form with a radius of curvature less than the final radius of the structure to be formed.

38. A method as claimed in claim **36** and including the step of passing said strip through a pair of pinch rollers and a ring roller adjustable relative to one of said pinch rollers such as to cause said strip to adopt said desired radius of curvature.

39. A method as claimed in claim **36** and including the step of passing the strip through a pair of pinched rollers, the axis of rotation of which are displaced relative to each other such as to cause said strip to adopt a bend along its length thereby to impart a sideways bend into said strip and create a strip having one edge longer than the other.

40. A method as claimed in claim **36** and including the step of applying an adhesive to portions of said strip which will be overlapping when formed into a tubular structure.

41. A method as claimed in claim **36** in which the adhesive is applied by applying the adhesive as a strip of adhesive to said strip of material.

42. A method as claimed in claim **39** and including the step of protecting said strip of adhesive by applying a protective coating to at least one surface thereof and removing said protective coating prior to applying said adhesive onto said strip which forms said tubular structure.

43. A method as claimed in claim **36** and including the step of providing a tubular core and winding said strip onto said core so as to produce a tubular structure having an inner core and an outer casing of helically wound material.

44. A method as claimed in claim **42** and including the step of forming said tubular core by roll forming a strip of material along its length and seam welding abutting longitudinal edges.

45. A method as claimed in claim **42** including the step of forming said tubular core as a series of discrete lengths of tube and assembling them into a continuous or near continuous length prior to winding said strip material onto said core.

46. A method as claimed in claim **42** including the step of forming said tubular core as a length of extruded pipe of a plastics material.

47. A method as claimed in claim **42** including the step of providing the core as discrete lengths of ceramic tube.

48. A tubular structure manufactured according to the method of claim **36**.

49. (canceled)

50. (canceled)

* * * * *