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(54) **PRODUCTION OF CLAD PIPES**

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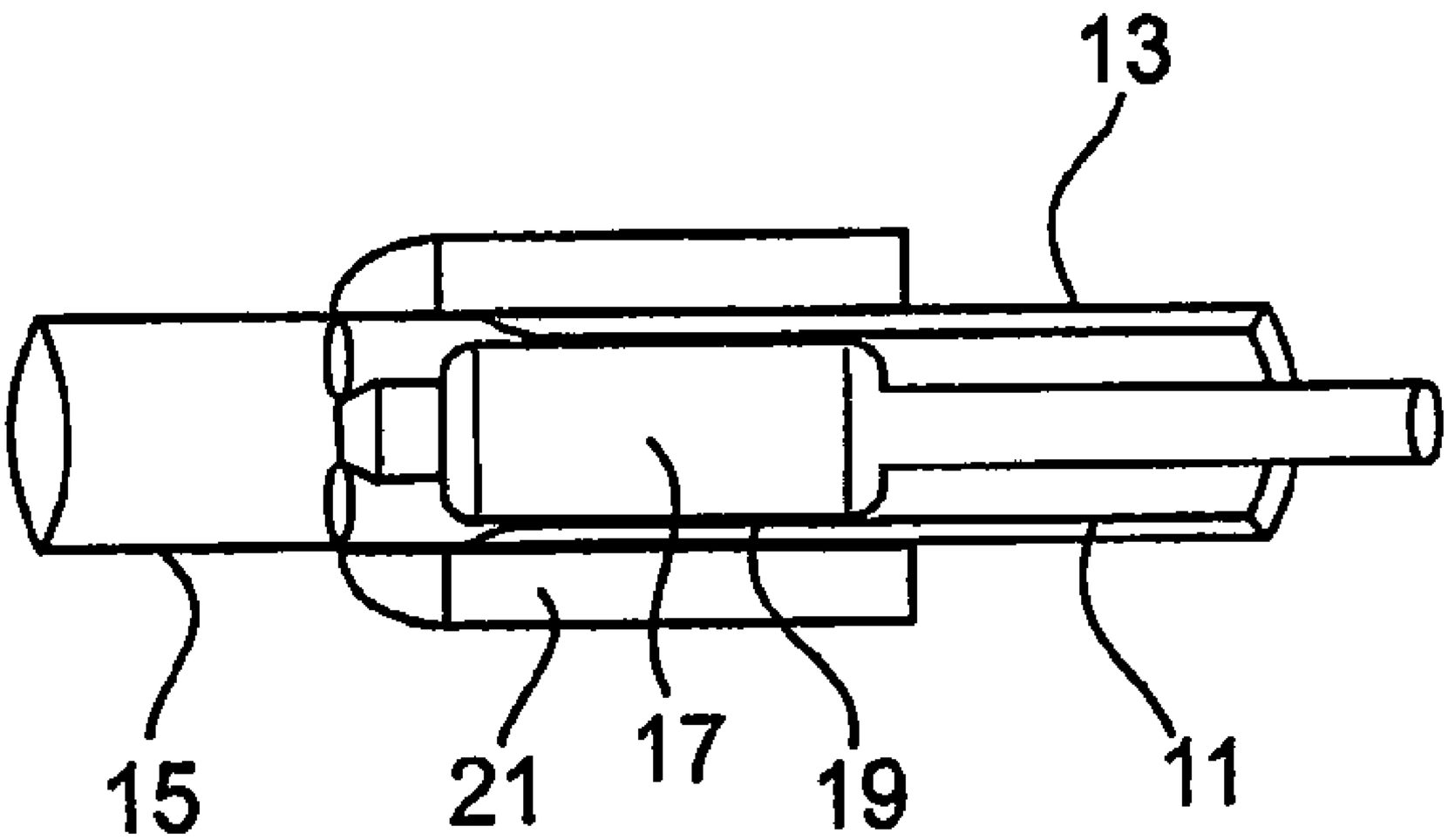
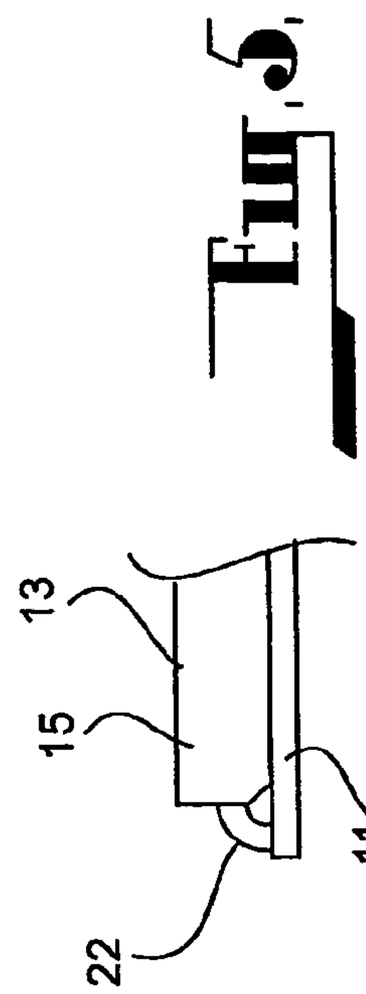
(57) **ABSTRACT**

A method of manufacturing a tubular structure such as a clad pipe (**10**) having inner and outer pipe sections (**11, 13**) with an interference fit therebetween and also a clad pipe (**10**) manufactured in accordance with that method. The method comprises the following steps: (a) positioning two pipe sections one within the other to provide an assembly (**15**) comprising the inner pipe section (**11**) and the outer pipe section (**13**); (b) radially expanding a portion of the inner pipe section (**11**) into engagement with the surrounding portion of the outer pipe section (**13**) using an expansion tool (**17**); (c) continuing to radially expand said portion of the inner pipe section (**11**) to plastically expand said portion of the inner pipe section (**13**) and elastically expand the surrounding portion of the outer pipe section (**13**); and (d) repeating steps (b) and (c) for one or more further portions of the inner pipe section (**11**). Because the inner pipe section (**11**) is radially expanded into a condition which it undergoes plastic deformation and the outer pipe section (**13**) is radially expanded to undergo elastic but not plastic deformation, interference between the inner and outer pipe sections is achieved due to the residual tensile stress in the outer pipe section (**13**) and the residual compression stress in the inner pipe section (**11**). The method may also involve establishing a metallurgical bond between the confronting surfaces of the two pipe sections (**11, 13**).





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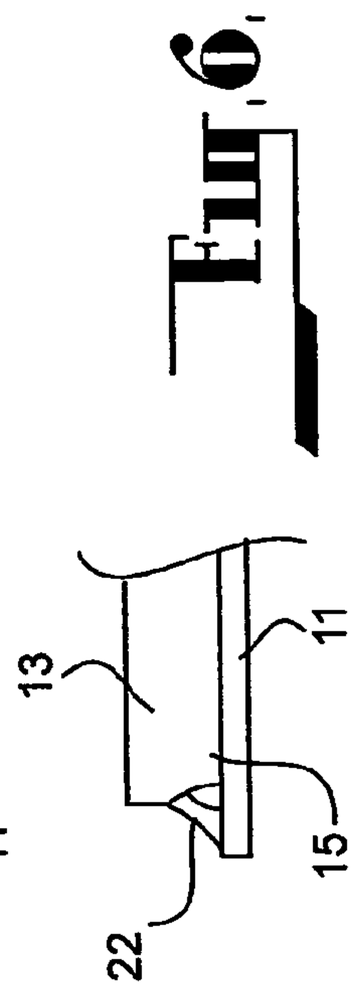

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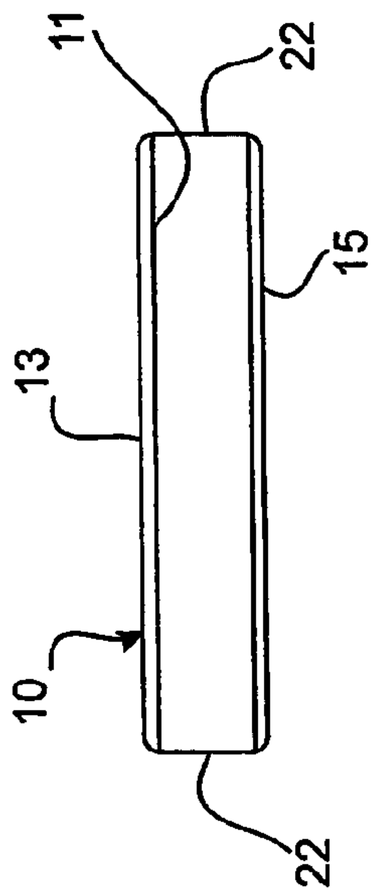

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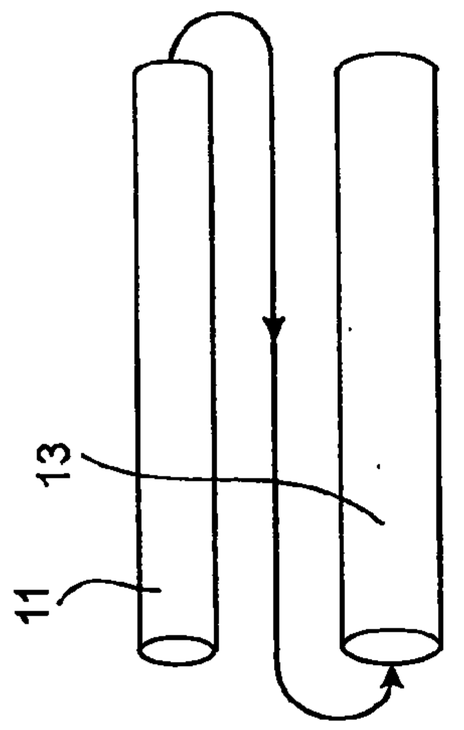

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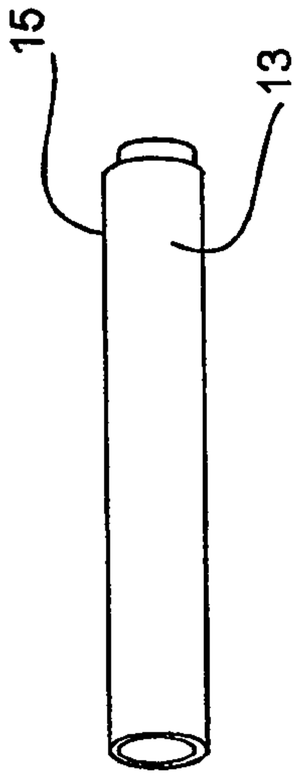

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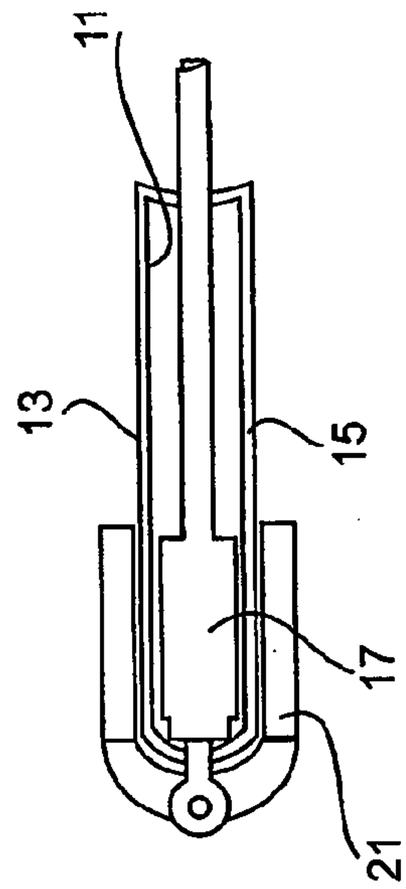

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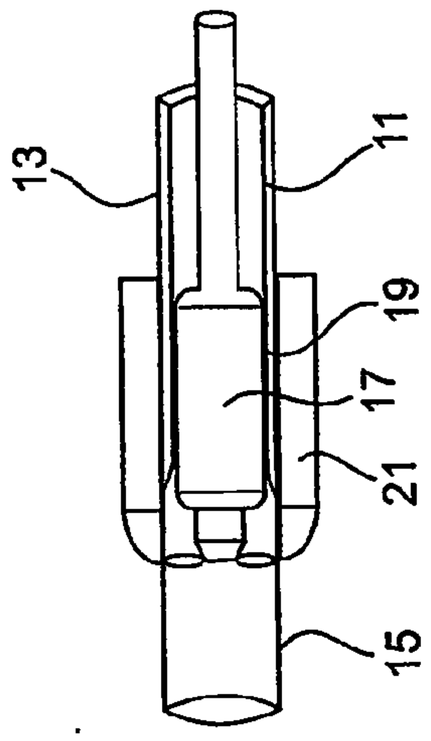

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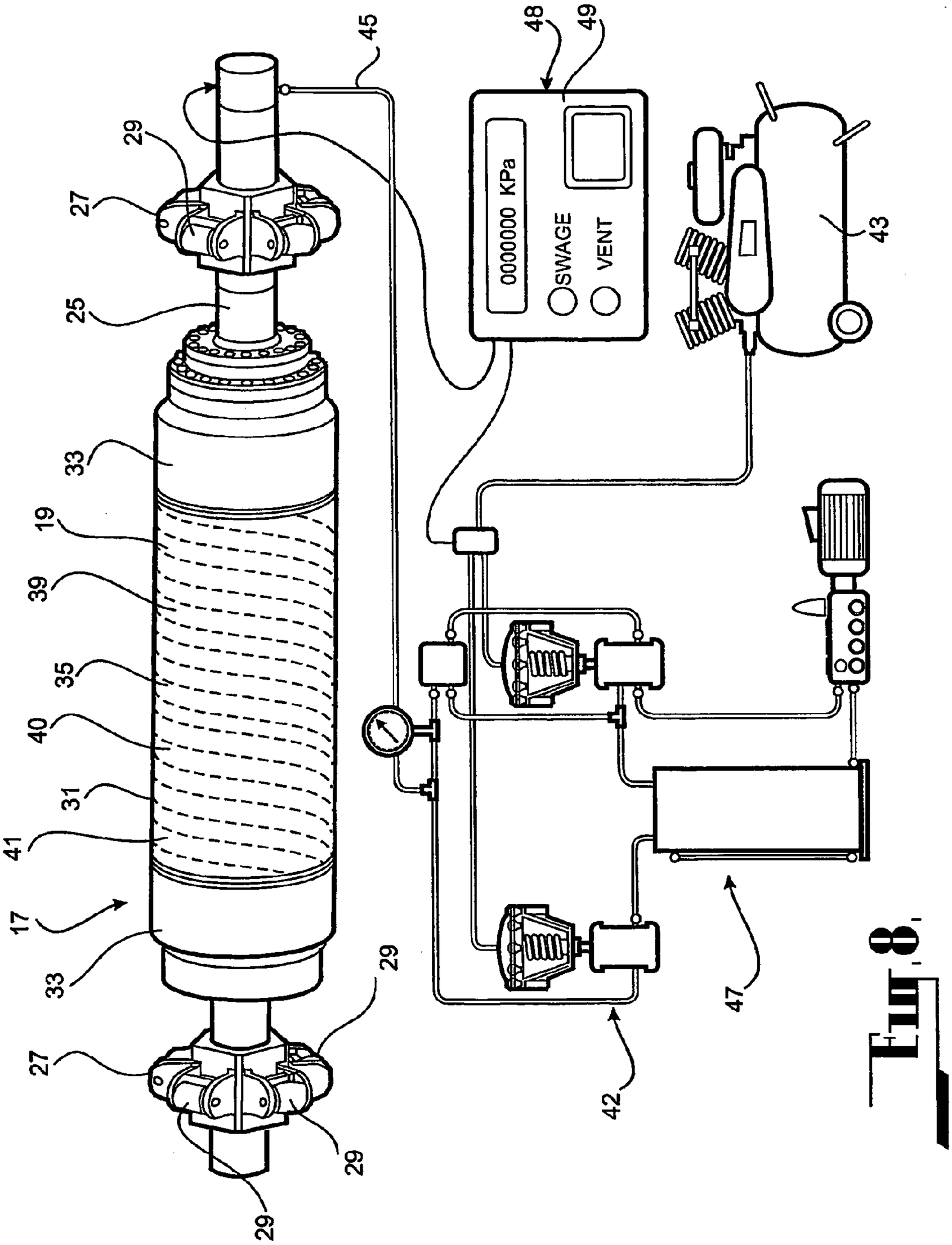
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FIG. 8

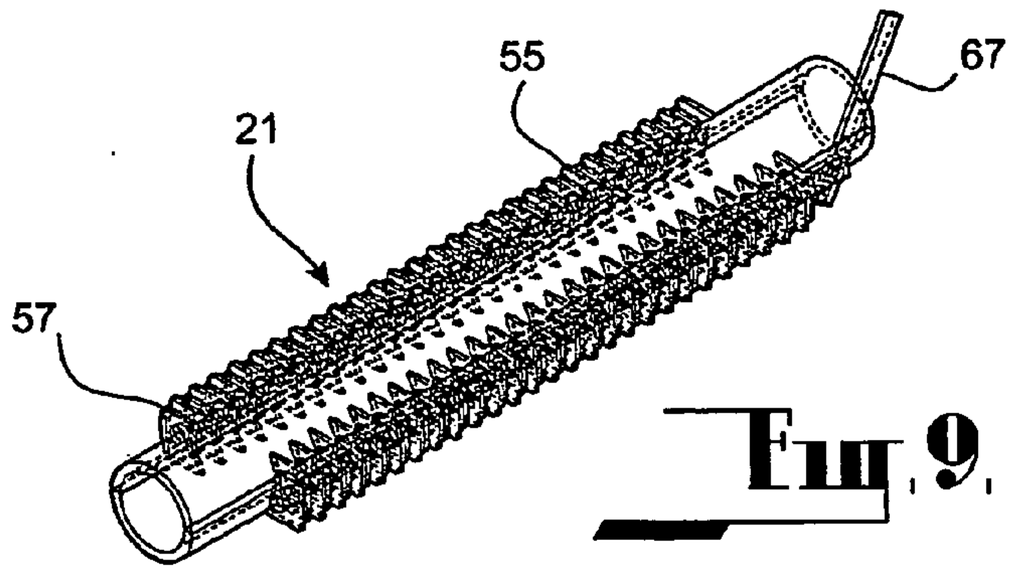

Fig. 9

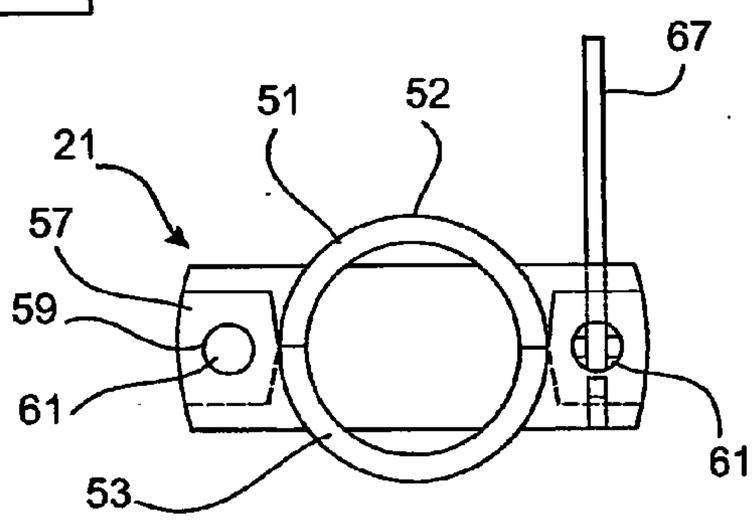

Fig. 10

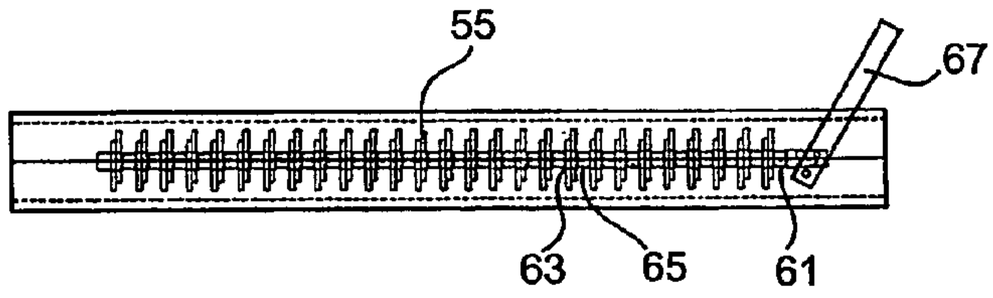

Fig. 11

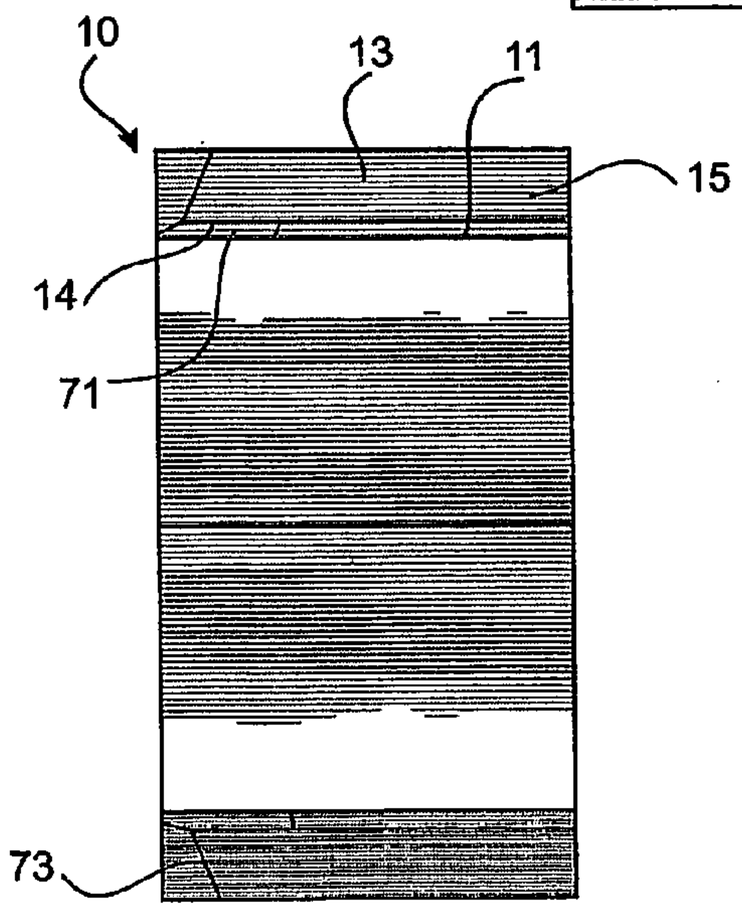

Fig. 12

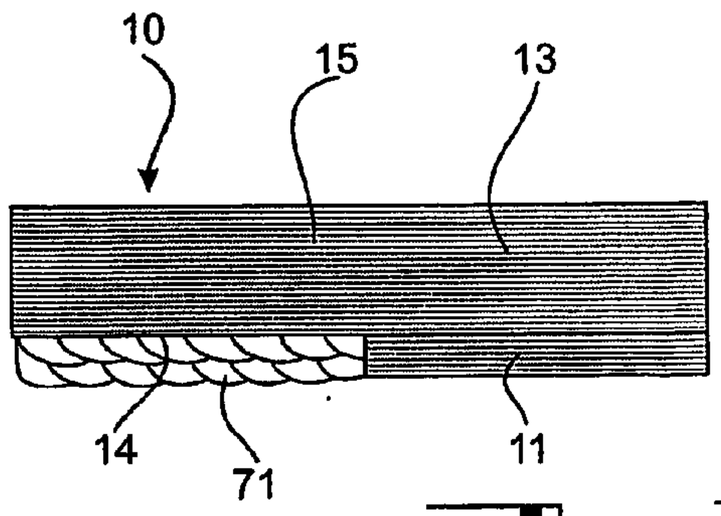

Fig. 13

PRODUCTION OF CLAD PIPES

FIELD OF THE INVENTION

[0001] This invention relates to the production of clad pipes and other tubular structures having inner and outer tubular sections with an interference fit therebetween.

BACKGROUND ART

[0002] A clad pipe typically comprises inner and outer pipe sections with an interference fit therebetween. Clad pipes typically combine the required properties of the inner and outer pipe sections. A clad pipe may, for example, have an inner pipe section selected for particular characteristics such as heat and/or corrosion resistance, and an outer pipe section also selected for particular characteristics such as relatively low cost, high strength, ductility and/or weldability.

[0003] There are various known manufacturing processes by means of which clad pipes can be produced. One known process involves the application of hydraulic pressure to the interior of the inner pipe section to cause it to radially expand into frictional engagement with the outer pipe section. This procedure involves plugging the ends of the inner pipe section and introducing hydraulic fluid (typically water) into the interior of the inner pipe section, thereby causing it to undergo radial expansion. There are, however, several disadvantages with such a procedure, one of which is that it is necessary to make provision for egress of air contained in the initial clearance space between the inner and outer pipe sections. For this purpose, vent holes are drilled in the ends of the outer pipe section. While this does allow trapped air to escape, it also requires that part of the resulting clad pipe needs to be scrapped because of the presence of the vent holes. A further disadvantage arises because of the care needed to ensure that there is no water ingress between the inner and outer pipe sections, as water ingress can lead to welding and other quality problems. A still further disadvantage is that pistons used for closing the ends of the inner pipe section can cause deformation or other damage to the clad pipe.

[0004] Another manufacturing process involves subjecting the inner and outer pipe sections to thermal treatment prior to their being brought together. Specifically, the outer pipe is heated in order to cause it to undergo radial expansion, and the inner pipe section is cooled in order to cause it to undergo radial contraction. The contracted inner pipe section is inserted into the expanded outer pipe section, and the pipe sections returned to ambient temperature, with the result that the outer pipe section contracts onto the inner pipe section and the inner pipe section expands onto the outer pipe section, thereby providing an interference fit therebetween. Such a process can be complicated, as it does require facilities for heating and cooling the pipe sections.

[0005] It is against this background, and the problems and difficulties associated therewith, that the present invention has been developed.

[0006] The above discussion of the background to the invention is intended to facilitate an understanding of the present invention. However, it should be appreciated that the discussion is not an acknowledgment or admission that any of the material referred to was published, known or part of the common general knowledge in Australia as at the priority date of the application.

DISCLOSURE OF THE INVENTION

[0007] According to a first aspect of the invention there is provided a method of manufacturing a tubular structure having inner and outer tube sections with an interference fit therebetween, the method comprising the following steps:

[0008] (a) positioning two tube sections one within the other to provide an assembly comprising an inner tube section and outer tube section;

[0009] (b) radially expanding a portion of the inner tube section into engagement with the surrounding portion of the outer tube section;

[0010] (c) continuing to radially expand said portion of the inner tube section to plastically expand said portion of the inner tube section and elastically expand the surrounding portion of the outer tube section; and

[0011] (d) repeating steps (b) and (c) for one or more further portions of the inner tube section.

[0012] Because the inner tube section is radially expanded into a condition which it undergoes plastic deformation and the outer tube section is radially expanded to undergo elastic but not plastic deformation, interference between the inner and outer tube sections is achieved due to the residual tensile stress in the outer tube section and the residual compression stress in the inner tube section.

[0013] Because said further portions of the inner tube section are expanded sequentially, air trapped between the inner and outer tube sections can readily escape and not be trapped between the inner and outer tube sections in the completed tubular structure.

[0014] Preferably, the expansion steps (b) and (c) are applied sequentially from one end. of the assembly to the other. However, the sequence can be varied, if desired. For example, the sequence can commence at a location intermediate the ends of the assembly and progressively advance towards one end and then the other.

[0015] The confronting surface of either one or both of the two tube sections can be pre-treated to enhance a mechanical bond therebetween, if so desired. Typically, the pretreatment may involve roughening the surface, such as by way of an abrasive blasting process.

[0016] The method may also involve establishing a metallurgical bond between the confronting surfaces of the two tube sections.

[0017] The ends of the tubular structure may be sealed in any appropriate way to prevent ingress of moisture and any other contaminants between the inner and outer tube sections. The ends of the tubular structure may be sealed by, for example, welding.

[0018] At one end (and preferably at both ends) of the tubular structure, the end of one tube section may be disposed inwardly of the corresponding end of the other tube section, and the resultant exposed bond portion of the other tube section clad with an overlay forming a metallurgical bond with the other tube section and also a metallurgical seal between the two tube sections.

[0019] Preferably, the inner tube section comprises said one tube section and the outer tube section comprises said other tube section.

[0020] Preferably, the overlay comprises a weld overlay.

[0021] While the expansion force may be applied in any suitable way, an expansion apparatus having a cylindrical press surface is particularly suitable for the purpose. With such apparatus, the press surface may be defined by an inflatable structure whereby inflation thereof applies an expansion force to the inner surface of the inner tube portion. The inflation may be achieved by way of an inflation fluid.

[0022] The inflatable structure may be mounted on a carriage moveable axially along the interior of the inner tube portion.

[0023] According to a second aspect of the invention there is provided a tubular structure manufactured according to the first aspect of the invention. The tubular structure may comprise a clad pipe.

[0024] According to a third aspect of the invention there is provided a tubular structure having inner and outer tube sections with an interference fit therebetween, an end of one tube section being disposed inwardly of the corresponding end of the other tube section, and the resultant exposed portion of the other tube section being clad with a weld overlay providing a metallurgical seal between the inner and outer tube sections.

[0025] Preferably, the inner tube section comprises said one tube section and the outer tube section comprises said other tube section.

[0026] Preferably, such a metallurgical seal is provided at each end of the tubular structure.

[0027] Accordingly to a fourth aspect of the invention there is provided apparatus for use in the production of a tubular structure having inner and outer tube sections with an interference fit therebetween, the apparatus comprising a base structure adapted to engage and travel along the interior surface of the inner tube section, and a press structure carried on the base structure, the press structure defining a cylindrical press surface for pressing engagement against the interior surface of the inner tube upon inflation thereof.

[0028] Preferably, the base structure comprises a support on which the press structure is carried and a plurality of roller assemblies carrying the support, the roller assemblies being adapted for location against and rolling movement along the interior surface of the inner tube section.

[0029] Conveniently, there are two roller assemblies in spaced apart relationship, with the press structure being intermediate the roller assemblies.

[0030] Preferably, the press structure comprises an inflatable structure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The invention will be better understood by reference to the following description of several specific embodiments thereof directed to the manufacture of a clad pipe. The description will be made with reference to the accompanying drawings in which:

[0032] FIGS. **1** to **7** illustrate schematically a sequence of steps for manufacture of a clad pipe according to a first embodiment;

[0033] FIG. **8** is a schematic perspective view of apparatus incorporating an inflatable structure used in the manufacture of the pipe;

[0034] FIG. **9** is a schematic perspective view of a containment collar structure for limiting the extent of radial expansion of the pipe assembly;

[0035] FIG. **10** is an end view of the collar structure;

[0036] FIG. **11** is a side view of the collar structure;

[0037] FIG. **12** is a fragmentary sectional view showing one end of a clad pipe according to a second embodiment; and

[0038] FIG. **13** is a fragmentary sectional side view, on an enlarged scale, showing the seal between the inner and outer pipe sections of the clad pipe of FIG. **12**.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0039] The first embodiment, which is shown in FIGS. **1** to **11**, is directed to the manufacture of a clad pipe **10** comprising an inner pipe section **11** and an outer pipe section **13**. The two pipe sections **11**, **13** are an interference fit with respect to each other to provide a pipe assembly **15**. The arrangement is such that the inner pipe section **11** provides a liner for the outer pipe section **13** in the assembly **15**.

[0040] In this embodiment, the inner pipe section **11** comprises a stainless steel liner of 1.6 mm wall thickness, and the outer pipe section **13** comprises a carbon steel pipe of 6.35 mm wall thickness. The two pipe sections **11**, **13** are shown in FIG. **1** prior to insertion of the inner pipe section **11** within the outer pipe section **13**, and are shown in FIG. **2** after such insertion.

[0041] Prior to insertion of the inner pipe section **11** into the outer pipe section **13**, the contact surfaces thereof (being the outside surface of the inner pipe section **11**, and the inside surface of the outer pipe section **13**) are roughened by way of an abrasive blasting process (such as sand blasting) to achieve an SA 2.5 profile.

[0042] Apparatus in the form of an expansion tool **17** is then inserted into the pipe assembly **15**, as shown in FIG. **3**. The expansion tool **17** is sequentially moved along the pipe assembly **15** from one end thereof to the other, performing an expansion process progressively along the pipe assembly **15**, as shown in FIG. **4** and as will be described in more detail later. There is an overlap between each expansion step and the next, typically by about 300 mm in this embodiment.

[0043] The expansion tool **17** has a cylindrical press surface **19** which is adapted to undergo radial expansion (as will be described in detail later), so as to apply a radial expansion force to that portion of the inner tube section **11** with which it is engaged.

[0044] A containment collar structure **21** operates in association with the expansion tool **17** and is positioned around the pipe assembly **15** in registration with the cylindrical press surface **19** of the expansion tool **17**.

[0045] Radial expansion of the cylindrical press surface **19** of the expansion tool **17** applies a radially outward force to the inside wall surface of the inner tube section **11**. The outward force causes the portion of the inner tube section **11** engaged by the cylindrical press surface **19** to expand outwardly and move into engagement with the outer pipe section **13**. The outward force is continued to be applied to the portion of the inner pipe section **11** to cause plastic deformation thereof while simultaneously elastically deforming the outer pipe section **13**. Expansion continues until the elastic limit of the outer pipe section **11** is almost reached, whereupon the press surface **19** provided by the tool **17** is retracted. The tool **17** is then advanced along the pipe assembly **15**, with an overlap of approximately 300 mm. The expansion process is then repeated so as to expand the surrounding portion of the inner pipe section **11** to cause plastic deformation thereof and expand the surrounding portion of the outer pipe section **17** elastically in a similar fashion to that previously. The process is repeated sequentially until the entire pipe assembly **15** has been treated.

[0046] Because the inner pipe section **11** is radially expanded into a condition which it undergoes plastic deformation and the outer pipe section **13** is radially expanded to undergo elastic but not plastic deformation, interference between the inner and outer pipe sections **11**, **13** is achieved due to the residual tensile stress in the outer pipe section **13** and the residual compression stress in the inner pipe section **11**.

[0047] As various portions of the inner pipe section **11** are expanded sequentially, air trapped between the inner and outer pipe sections **11**, **13** can readily escape and not be trapped between the inner and outer pipe sections in the completed pipe assembly **15**.

[0048] The containment collar structure **21** is advanced progressively with the press surface **19** of the expansion tool **17**. The purpose of the containment collar **21** is to limit the extent of radial expansion of the outer pipe section **17** thereby ensuring that it does not expand to an extent whereby it undergoes plastic deformation.

[0049] Following completion of the expansion process, the ends of the pipe assembly **15** are sealed to prevent the ingress of moisture and any other contaminant material into the region between the two pipe sections **11**, **13**. In this embodiment, the ends are sealed by way of a seam weld **22**, as shown in FIG. **5**. The seam weld **22** can then be beveled, as shown in FIG. **6** in order to provide a neat finish.

[0050] The completed clad pipe **10** is illustrated in FIG. **7** of the drawings, and comprises the inner pipe section **11** and the outer pipe section **13**, with an interference fit therebetween. The interference fit provides a gripping force between the two pipe sections **11**, **13** arising from the residual tensile stress in the outer pipe section **13** and the residual compression stress in the inner pipe section **11**.

[0051] The completed clad pipe **10** is able to comply with international standard API 5LD.

[0052] The expansion tool **17** is illustrated in more detail in FIG. **8** of the drawings.

[0053] The expansion tool **17** comprises a base **25** in the form of a shaft carried on spaced apart roller assemblies **27**. The base **25** and roller assemblies co-operate to function as a carriage. Each roller assembly **27** comprises a plurality of circumferentially spaced rollers **29** adapted to engage against, and roll along, the interior surface of the inner pipe section **11**. With this arrangement, the roller assemblies **27** centrally locate the shaft **25** axially within the interior of the inner pipe section **11**. A press structure **31** is supported on the shaft **25** between the two roller assemblies **27**. The press structure **31** comprises two rigid end sections **33** and an intermediate section **35** therebetween. The intermediate section **35** comprises a resiliently flexible cylindrical wall **39** supported between the end sections **33** to define an inflatable bladder **40**. The cylindrical wall **39** has an exterior surface **41** which defines the press surface **19** for engaging and radially expanding portions of the interior surface of the inner pipe section **11**, as previously described. The bladder **40** is adapted to be inflated by an inflation fluid which in this embodiment comprises air. Inflation of the bladder **40** causes radial expansion of the cylindrical wall **39** to thereby apply force to the interior surface of the inner pipe section **11**.

[0054] The tool **17** further comprises control means **42** for selectively delivering an inflation fluid to the bladder and venting inflation fluid therefrom. The control means **42** includes an air compressor **43** coupled to an air line **45** through a pneumatic circuit **47**. The air line **45** communicates with the interior of the bladder **40** for delivery of inflation fluid into, and venting of inflation fluid from, the bladder. The control means **42** also has a control circuit **48** including a control panel **49**.

[0055] The containment collar structure **21** is illustrated in FIGS. **9**, **10** and **11** of the drawings. The collar structure **21** comprises a sleeve **51** adapted to fit around the exterior of the outer pipe section **13** for limiting the extent of possible radial expansion thereof, as previously explained. The sleeve **51** is split into two sections **52**, **53** to allow expansion of the sleeve for fitting onto the outer pipe section **13**. A locking mechanism **55** is provided for releasably locking the two sleeve sections **52**, **53** together to form the containment sleeve **51**. The locking mechanism **55** comprises a plurality of cleats **57** welded or otherwise secured to the two sleeve sections **52**, **53**. The cleats are provided with holes **59** which respectively move into alignment when the two sleeve sections **52**, **53** are assembled to form the sleeve. A locking pin **61** is received in each set of aligned holes. Each locking pin **61** comprises a plurality of axially spaced locking sections **63** and spacer sections **65** therebetween. The locking sections **63** are of larger diameter than the spacer sections **65** and are adapted to be received in the locking holes **59** to secure the two sleeve sections **52**, **53** together. Axial movement of the locking pin **61** can shift the locking sections **63** into and out of registration with the respective locking holes **59** when the locking pin **61** is in a condition in which the locking sections **63** are received in the holes **59**, the two sleeve sections **52**, **53** are secured together to form the sleeve **51**. On the other hand, when the locking pin **61** is in a condition in which the locking sections **63** are out of the holes **59**, the clearance space provided by the release sections **65** being of smaller diameter than the locking sections **63** allows limited separation of the two sleeve sections to facilitate insertion of the sleeve **51** onto, and withdrawal of the sleeve **51** from, the outer tube section **13**. A lever mechanism **67** is provided for effecting axial movement of the locking pin **61** between the two conditions.

[0056] In the first embodiment, the ends of the pipe assembly **15** are sealed by way of seam welds **22**, as shown in FIGS. **5** and **6**. Other sealing arrangements are, of course, possible.

[0057] One such other sealing arrangement is incorporated in the embodiment shown in FIGS. **12** and **13** which is similar in some respects to the first embodiment and so similar reference numerals are used to identify like parts.

[0058] In this embodiment, the inner pipe section **11** is shorter than the outer pipe section **13**, such that the ends of the inner pipe section are disposed inwardly of the corresponding ends of the outer pipe section in the pipe assembly **15**. The resultant exposed interior portion **14** of the outer pipe section **13** at each end thereof is clad with a weld overlay **71**, such as a hot wire TIG weld overlay.

[0059] While the ends of the inner pipe section **11** can be disposed inwardly of the corresponding ends of the outer pipe section **13** by any appropriate amount, it is typically in the order of 30 to 50 millimetres.

[0060] The weld overlay **71** forms a metallurgical bond with the carbon steel of the outer pipe portion **13**, providing a metallurgical seal between the inner and outer pipe sections and also allowing the ends of the pipe assembly **15** beyond the seal to be cut or machined in order to suit requirements of a particular installation provided that the integrity of the seal is not disturbed.

[0061] A bevel **73** may be formed at the end of the clad pipe **10** for welding purposes.

[0062] Typically, lengths of clad pipe **10** are welded one to another in a pipe laying operation, with adjacent ends of lengths of pipe assembly being welded together by way of a girth welding procedure. If a defect or other fault were to occur in the girth weld, it is possible to perform rectification work without breaching the metallurgical seal between the inner and outer pipe sections **11**, **13**. The rectification work typically involves cutting the girth weld from between the lengths of clad pipe **10**, re-beveling the adjacent pipe ends and then rewelding the lengths of clad pipe together. In other words, the weld overlay **71** at each end of the clad pipe **10** provides a surplus length which is available for operations such as cutting and machining without breaching the integrity of the seal between the inner and outer pipe sections. This provides significant advantages during installation of a pipe line using lengths of the pipe assembly, as work can be performed on the pipe ends without breaking the seal between the inner and outer pipe sections **11**, **13**.

[0063] The previous embodiments have been directed to production of a clad pipe **10** involving a mechanical bond between the inner and outer pipe sections **11**, **13**.

[0064] A third embodiment (which is not shown) is similar to the previous embodiments, with the exception that there is a metallurgical bond between the inner and outer pipe sections **11**, **13**. This involves providing a metallurgical bonding agent on one or both of the confronting surfaces of the inner and outer pipe sections prior to the expansion process, and after the expansion process heating the pipe assembly **15** to a temperature sufficient to achieve a metallurgical bond between the inner and outer pipe sections. In this embodiment, the bonding agent comprises a nickel-based brazing powder applied to the exterior surface of the inner pipe section **11** in any appropriate manner, such as by spraying. Where the brazing powder is applied as a spay coat, the spraying action may be performed by way of a high velocity oxy fuel (HVOF), a high velocity air fuel (HVAF) or plasma spay.

[0065] Once the inner pipe section **11** is within the outer pipe section **13**, the space defined therebetween is closed and a vacuum applied and/or an inert gas (such as Argon) introduced into that closed space. The inner and outer pipe sections **11**, **13** are then radially expanded in a similar fashion to the previous embodiments. After the expansion process, the pipe assembly **15** is then passed through an induction coil capable of heating the pipe assembly to a temperature sufficient to braze the inner and outer pipe sections together, typically a temperature in the order of 1,100° C.

[0066] Any necessary finishing operations can then be performed on the pipe assembly, such as heat treatment and straightening operations.

[0067] From the forgoing, it is evident that the present embodiments each provide a simple yet highly effective arrangement for production of clad pipes.

[0068] While the embodiments have been described with reference to clad pipes, it should be understood that the invention is not limited to the production of clad pipes and can be applied to the production of any appropriate tubular structures having inner and outer tube sections with an interference fit therebetween.

[0069] Improvements and modifications may be made without departing from the scope of the invention.

[0070] Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

1. A method of manufacturing a tubular structure having inner and outer tube sections with an interference fit therebetween, the method comprising the following steps:

(a) positioning two tube sections one within the other to provide an assembly comprising an inner tube section and outer tube section;

(b) radially expanding a portion of the inner tube section into engagement with the surrounding portion of the outer tube section;

(c) continuing to radially expand said portion of the inner tube section to plastically expand said portion of the inner tube section and elastically expand the surrounding portion of the outer tube section; and

(d) repeating steps (b) and (c) for one or more further portions of the inner tube section.

2. A method according to claim 1 wherein the expansion steps (b) and (c) are applied sequentially from one end of the assembly to the other.

3. A method according to claim 1 wherein the expansion steps (b) and (c) commence at a location intermediate the ends of the assembly and progressively advance towards one end and then the other.

4. A method according to claim 1 wherein the confronting surface of either one or both of the two tube sections is pre-treated to enhance a mechanical bond therebetween.

5. A method according to claim 1 further including establishing a metallurgical bond between the confronting surfaces of the two tube sections.

6. A method according to claim 1 wherein the ends of the tubular structure are sealed.

7. A method according to claim 6 wherein the ends of the tubular structure may be sealed by welding.

8. A method according to claim 1 wherein at least one end of one tube section is disposed inwardly of the corresponding end of the other tube section, and the resultant exposed portion of the other tube section is clad with an overlay forming a metallurgical bond with the other tube section and also a metallurgical seal between the two tube sections.

9. A method according to claim 8 wherein the inner tube section comprises said one tube section and the outer tube section comprises said other tube section.

10. A method according to claim 8 wherein the overlay comprises a weld overlay.

11. A tubular structure manufactured according to the method of claim 1.

12. A tubular structure having inner and outer tube sections with an interference fit therebetween, an end of one tube section being disposed inwardly of the corresponding end of the other tube section, and the resultant exposed portion of the other tube section being clad with a weld overlay providing a metallurgical seal between the inner and outer tube sections.

13. A tubular structure according to claim 12 wherein the inner tube section comprises said one tube section and the outer tube section comprises said other tube section.

14. A tubular structure according to claim 12 wherein said metallurgical seal is provided at each end of the tubular structure.

15. Apparatus for use in the production of a tubular structure having inner and outer tube sections with an interference fit therebetween, the apparatus comprising a base structure including a support assembly adapted to carry a press structure and engage the interior surface of the inner tube section for movement therealong, the press structure defining a cylindrical press surface for pressing engagement against the interior surface of the inner tube upon inflation thereof.

16. Apparatus according to claim 15 wherein the support assembly comprises a plurality of roller assemblies carrying the support, the roller assemblies being adapted for location against and rolling movement along the interior surface of the inner tube section.

17. Apparatus according to claim 16 wherein there are two roller assemblies in spaced apart relationship, with the press structure being intermediate the roller assemblies.

18. Apparatus according to claim 17 wherein the press structure comprises an inflatable structure.

19. (canceled)

20. (canceled)

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