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(54) **PIPE TUBULAR REINFORCEMENT FORMING MACHINE, AND RELATED METHOD**

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See application file for complete search history.

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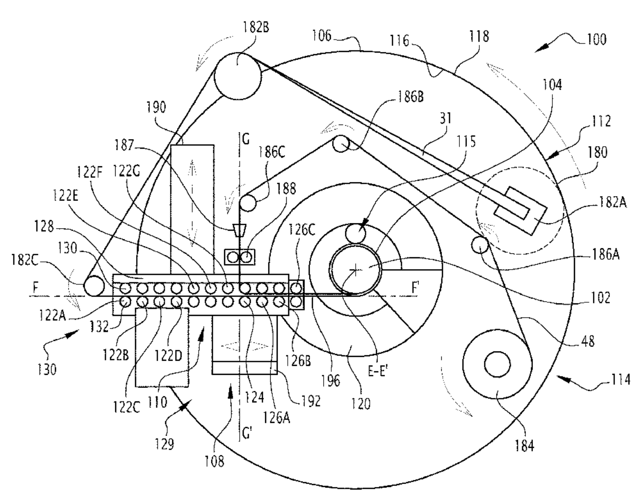
(57) **ABSTRACT**

A machine that includes a first feeder, able to unwind a first tape; a profiler comprising an upstream profiling stage able to profile the first tape to form a pre-profiled first tape; a second feeder, able to unwind a second tape, the second tape being a flat tape. A profiler that includes an intermediate joining stage able to receive the second tape as a flat tape from the second feeder and able to join the pre-formed first tape and the flat second tape; and at least a downstream profiling stage configured to jointly profile the first tape and the second tape received from the intermediate joining stage and form a combined profiled strip.

15 Claims, 6 Drawing Sheets



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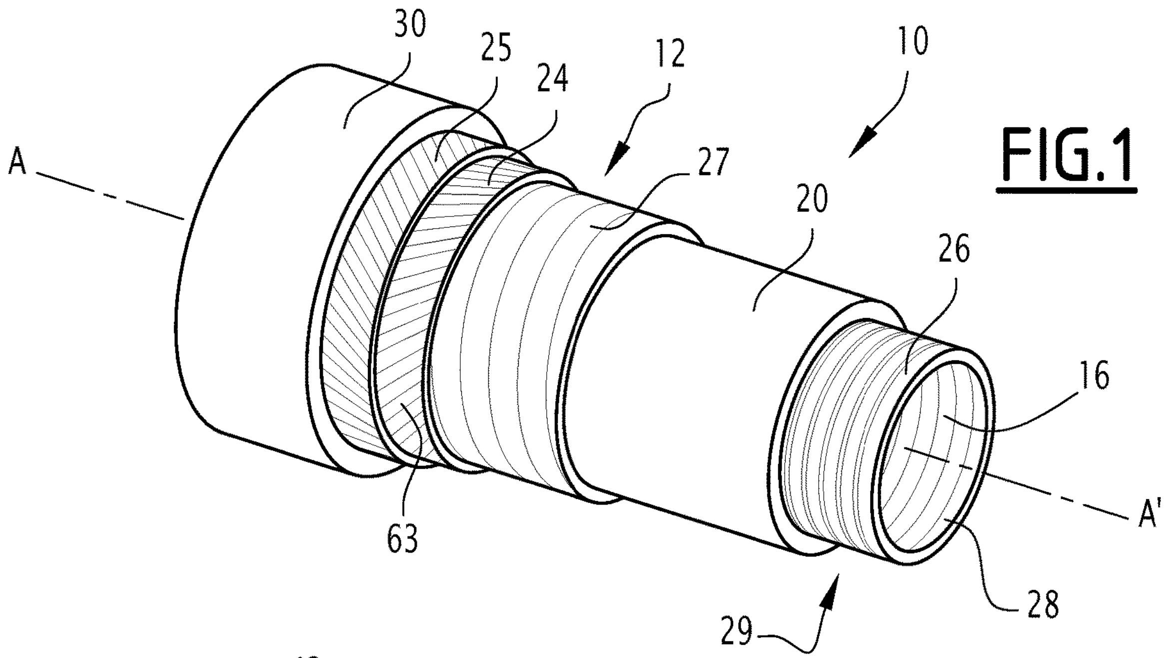


FIG.1

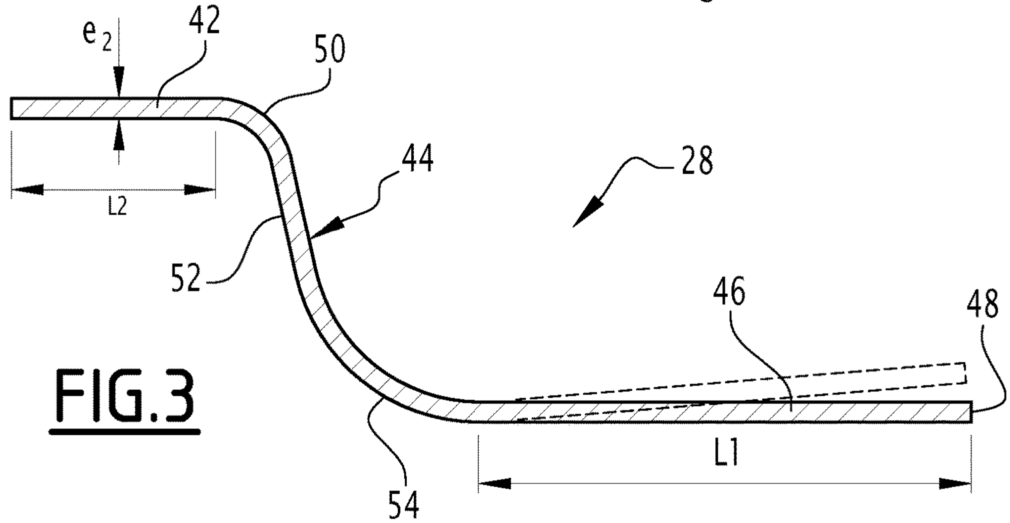


FIG.3

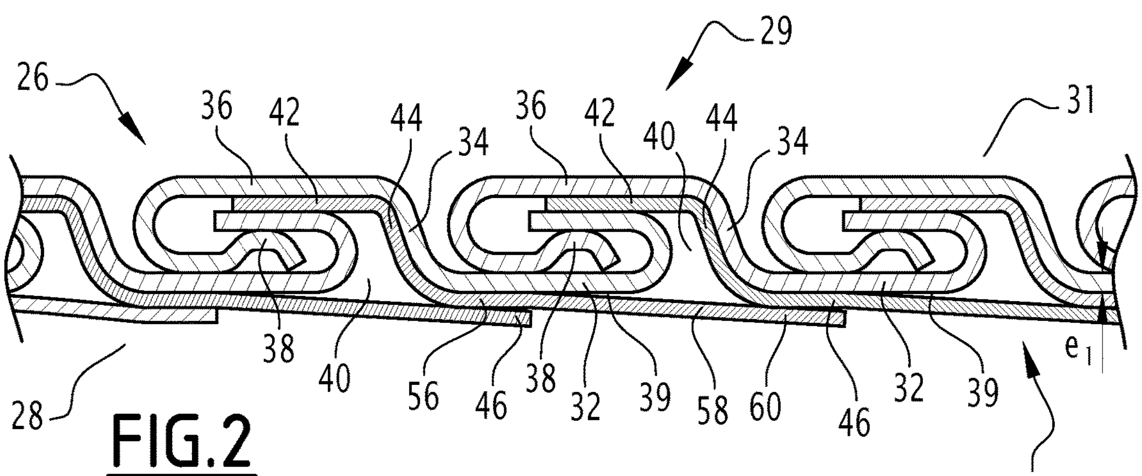
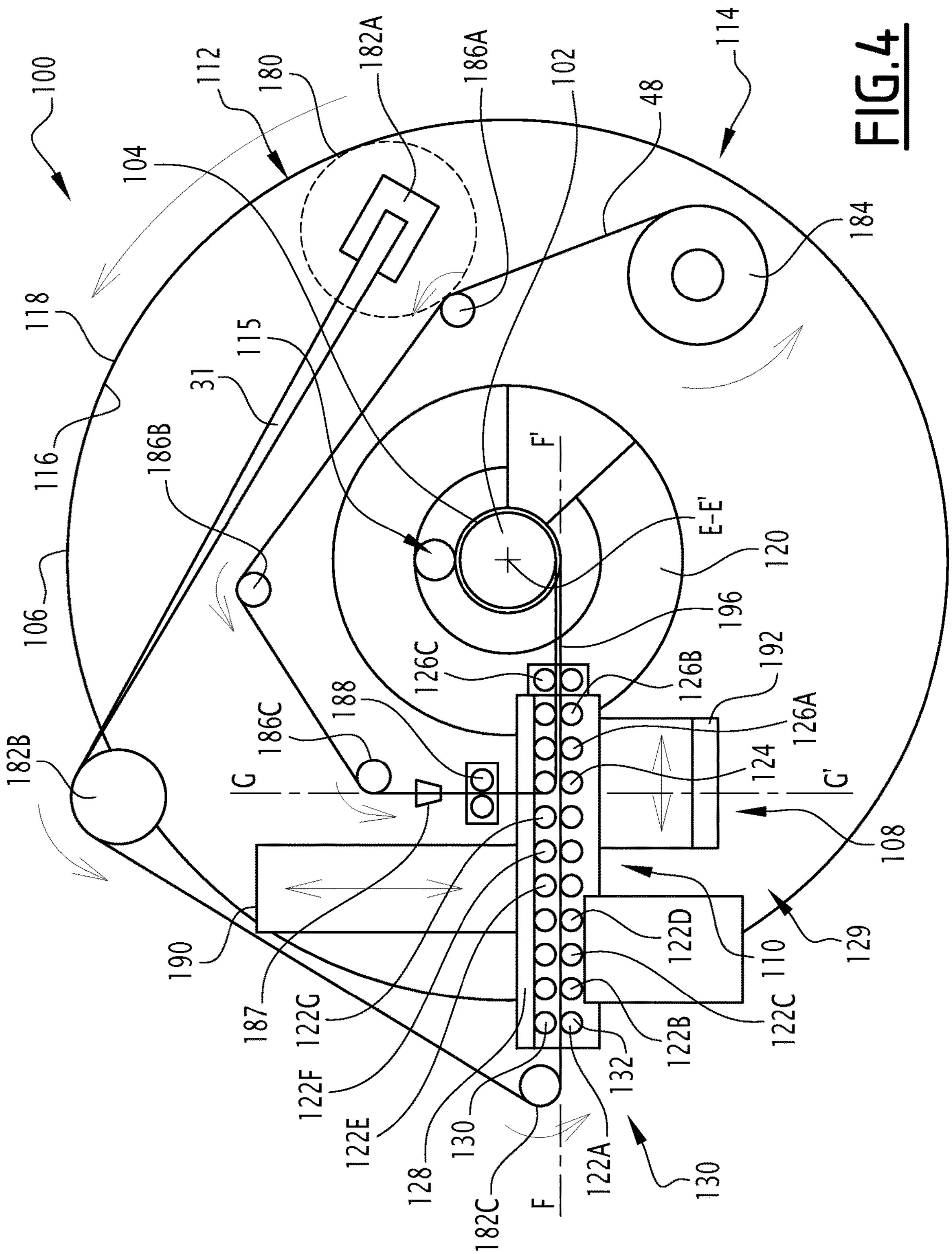


FIG.2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112
180
182A
186A
102
48
114
104
118
115
31
116
186B
184
F'
E-E'
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106
196
126C
126B
192
188
126A
186C
182B
G
124
G'
108
190
187
122G
122D
110
129
122C
122B
132
130
122F
122E
128
182C
F
122A

FIG.4

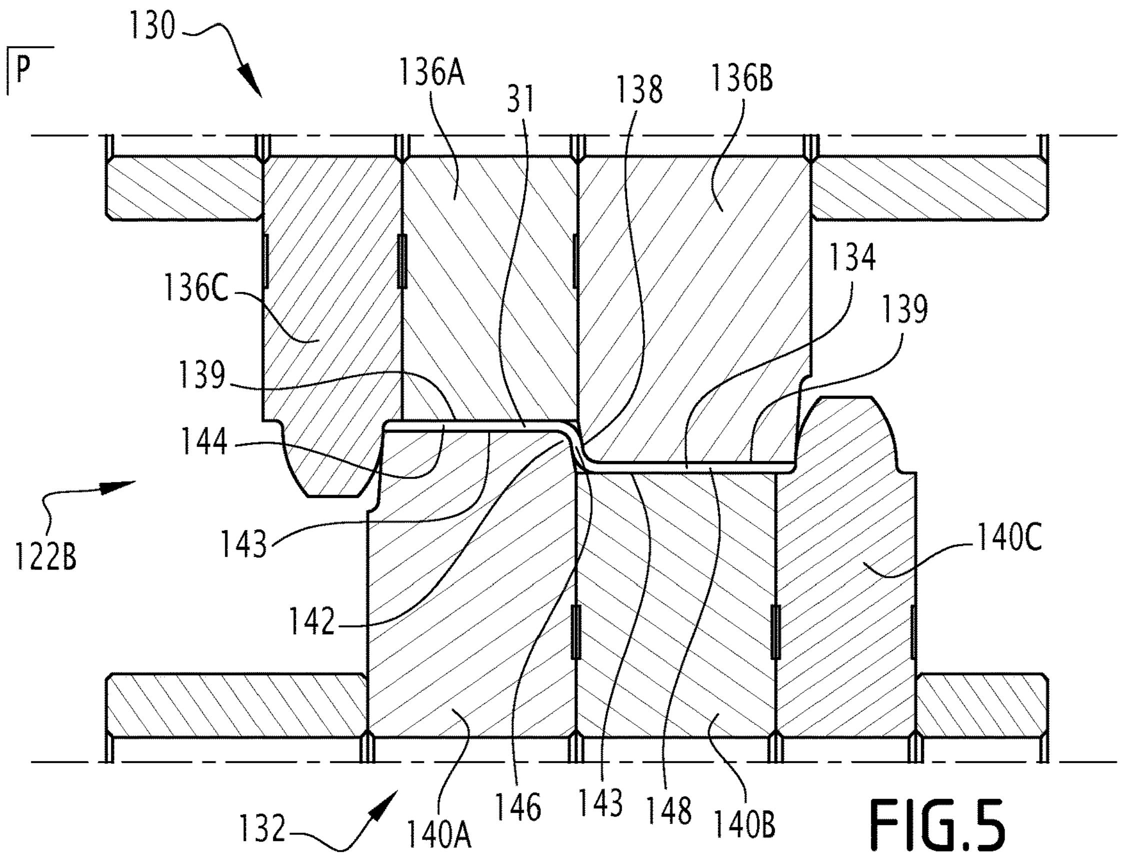
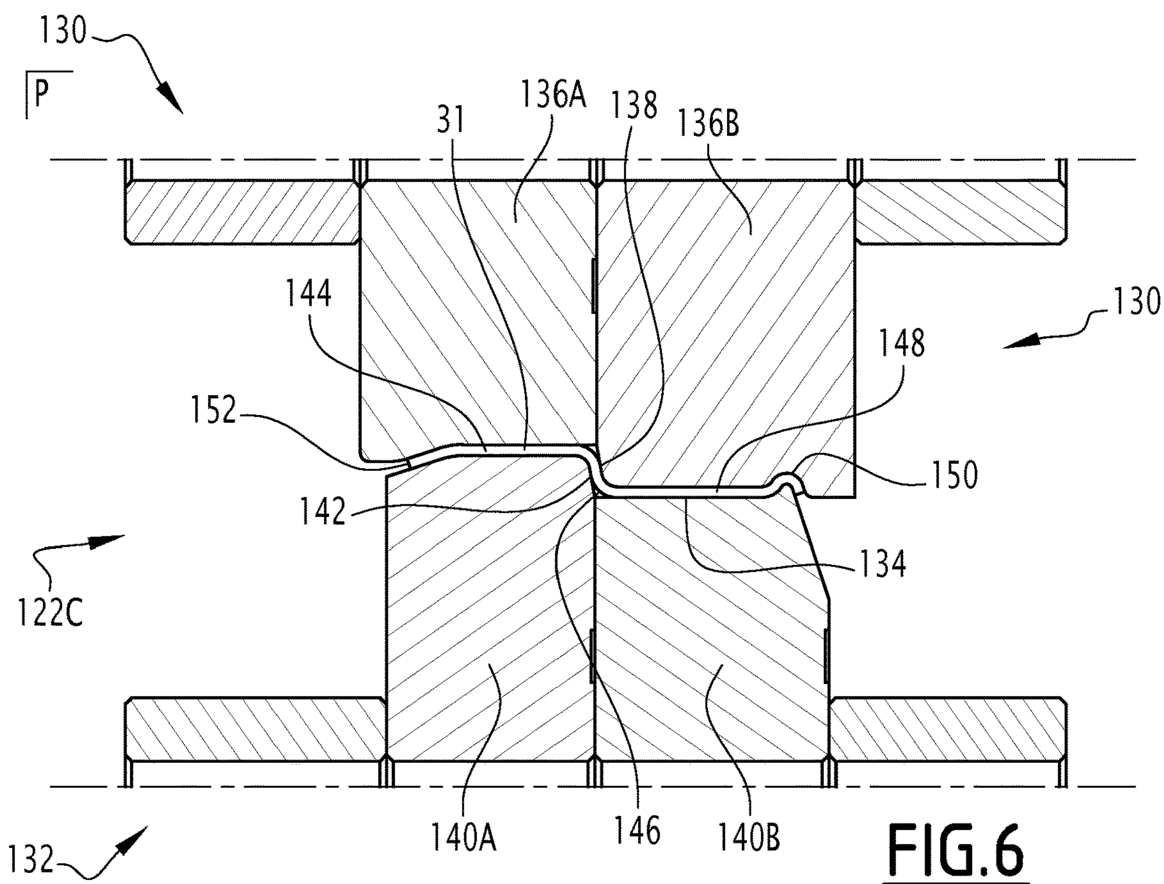

130
P
136A
31
138
136B
134
139
136C
139
144
143
122B
140C
142
132
140A
146
143
148
140B

FIG.5


130
P
31
136A
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136B
130
144
148
152
150
142
134
122C
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140A
146
140B

FIG.6

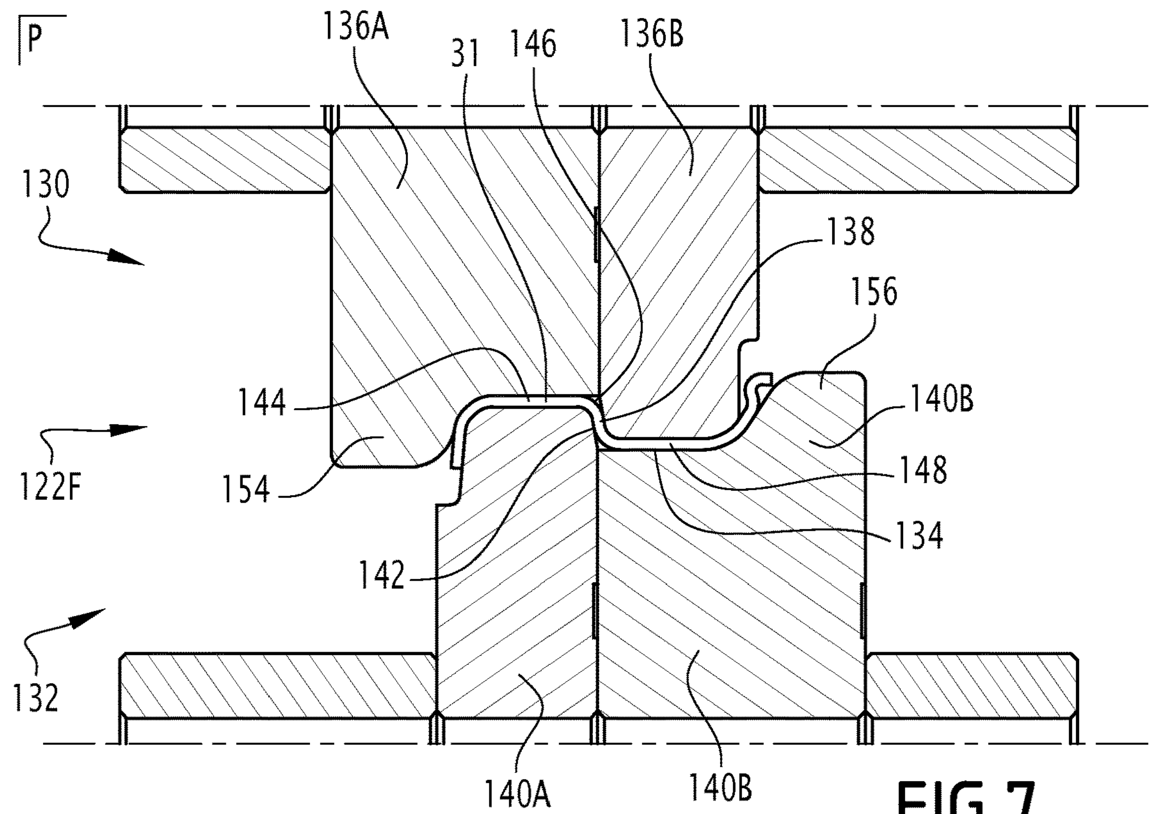

P
136A
31
146
136B
130
138
156
144
140B
122F
154
148
134
142
132
140A
140B

FIG.7

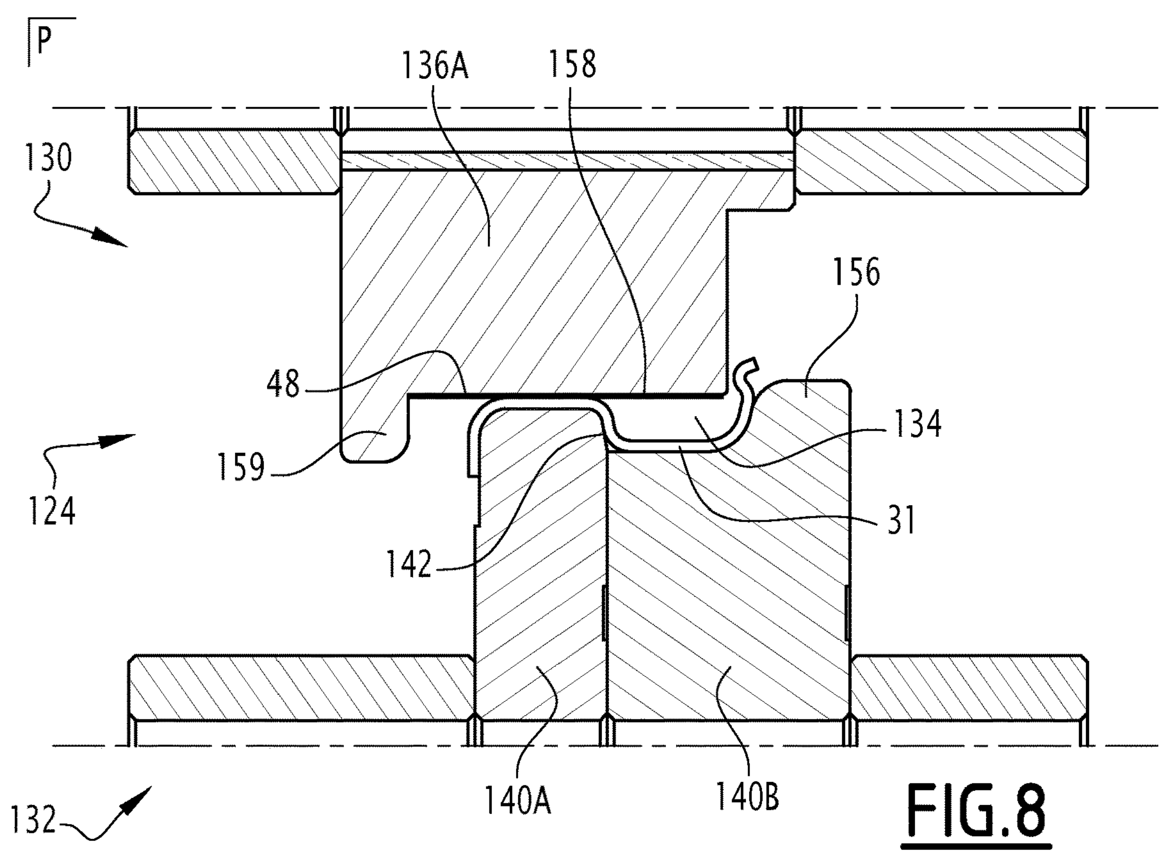

P
136A
158
130
156
48
134
159
124
31
142
140A
140B
132

FIG.8

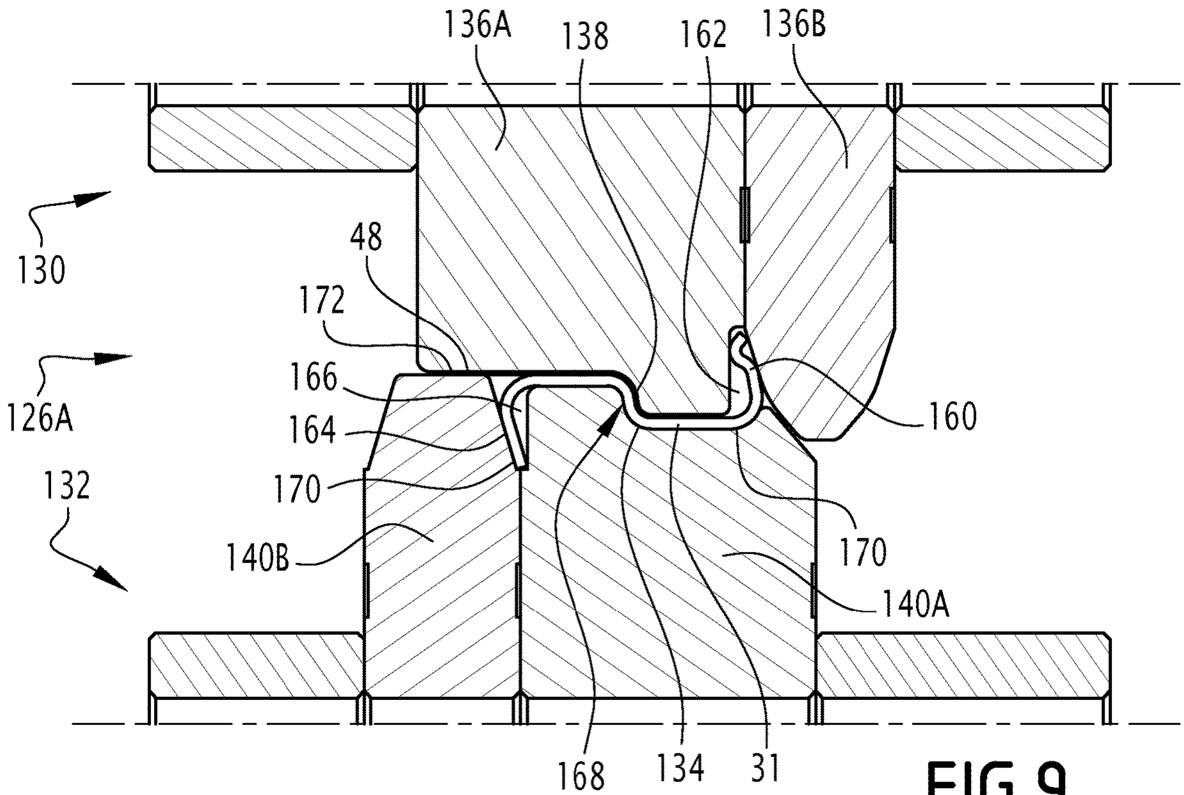
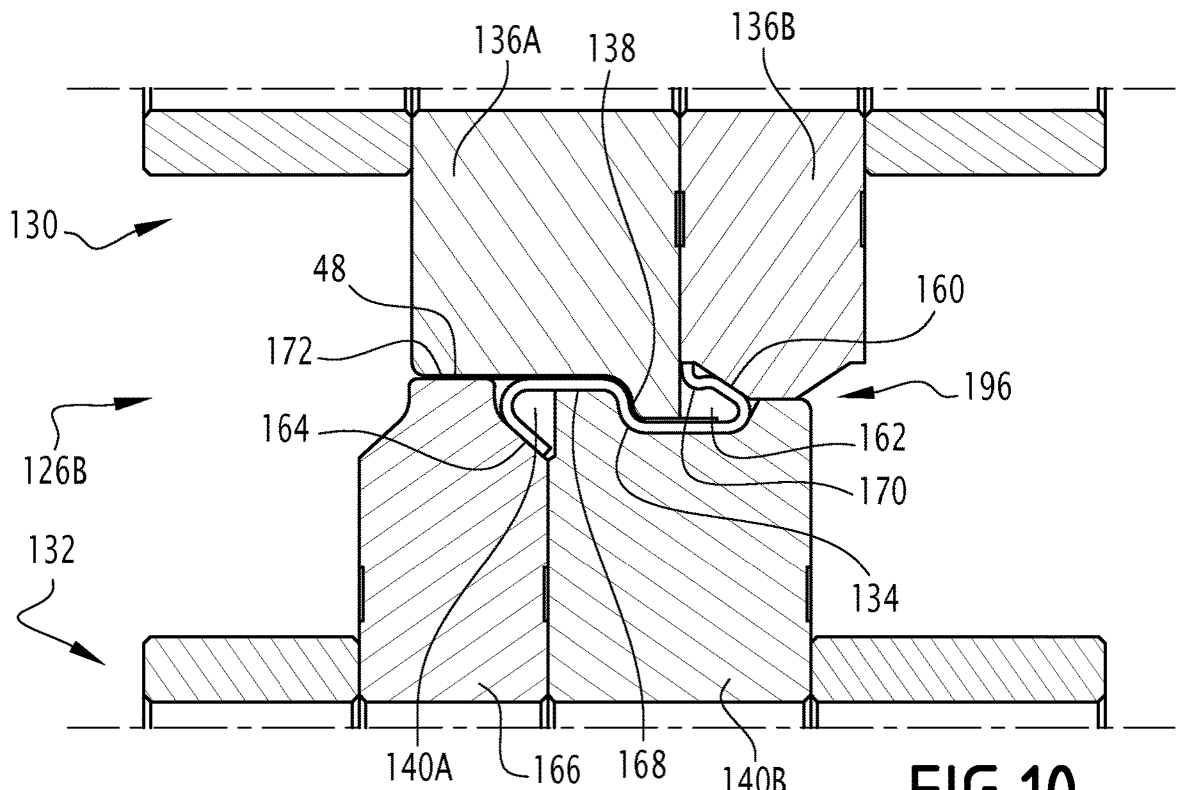

136A
138
162
136B
130
48
172
126A
166
164
170
132
140B
160
170
140A
168
134
31

FIG.9


136A
138
136B
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48
160
172
196
126B
164
162
170
132
134
140A
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168
140B

FIG.10

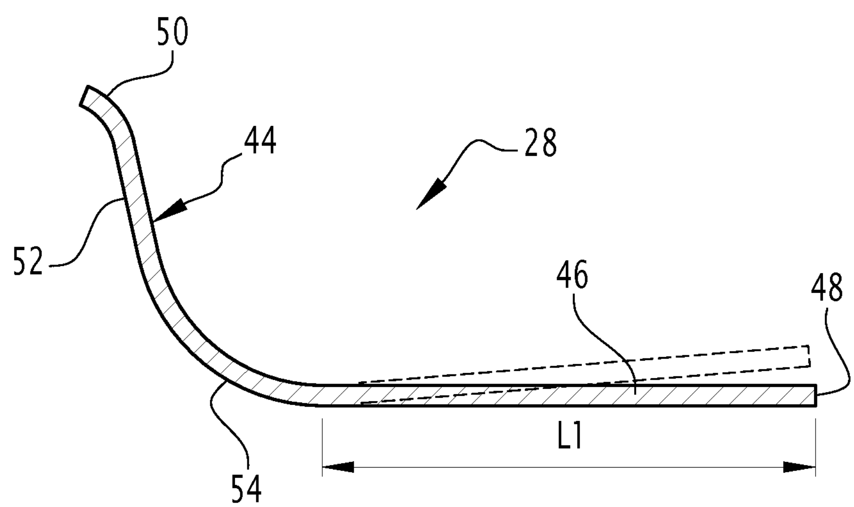

FIG.11

PIPE TUBULAR REINFORCEMENT FORMING MACHINE, AND RELATED METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a 35 U.S.C. §§ 371 national phase conversion of PCT/EP2018/085894, filed Dec. 19, 2018, which claims priority to European Patent Application No. 17306920.4, filed Dec. 22, 2017, the contents of which are incorporated herein by reference. The PCT International Application was published in the English language.

FIELD OF THE INVENTION

The present invention concerns a machine for forming a tubular reinforcement of a pipe, comprising:

a first feeder, able to unwind a first tape;

a profiler apparatus comprising at least an upstream profiling stage able to receive the first tape from the first feeder and to profile the first tape to form a pre-profiled first tape;

a second feeder, able to unwind a second tape, the second tape being a flat tape.

BACKGROUND OF THE INVENTION

The pipe is preferably a flexible pipe of the unbonded type, intended for transport of hydrocarbons through a body of water, such as an ocean, a sea, a lake or a river.

Such a flexible pipe is for example manufactured according with the standards API 17J (Specification for Unbonded Flexible Pipe, 4th edition—May 2014) and API RP 17B (Recommended Practice for Flexible Pipe, 5th edition—March 2014) established by the American Petroleum Institute.

The pipe is generally formed of an assembly of concentric and superposed layers. It is considered as «unbonded» if at least one of the layers of the pipe is able to move longitudinally with respect to the adjacent layers during flexure of the pipe. In particular, an unbonded pipe is a pipe without any bonding materials connecting layers forming the pipe.

The pipe is generally positioned through a body of water, between a bottom assembly, intended to collect the exploited fluid at the bottom of the body of water and a floating or fixed surface assembly, intended to collect and distribute the fluid. The surface assembly may be a semi-submersible platform, an FPSO or another floating or fixed assembly.

In certain cases, the flexible pipe comprises an internal carcass positioned in the pressure sheath. The carcass avoids collapse of the pressure sheath, under the effect of the external pressure, for example upon depressurization of the internal passage for circulation of fluid delimited by the pressure sheath.

The internal carcass is generally formed with a profiled metal tape, wound as a spiral. The turns of the tape are interlocked to each other. The turns delimit between them a helicoidal gap radially opening inwards into the central passage for circulation of the fluid.

The internal surface of the carcass therefore axially has a succession of recesses and bumps. The pipe is then generally referred to as «rough bore».

In certain cases, the circulation of the fluid along the carcass is perturbed by the raised/recessed portions defined on the carcass by the helicoidal gap.

This flow perturbation is sometimes considered as the source of vibratory phenomena within the flexible pipe, or even, when a resonance occurs, of pulses induced by the circulation of fluid («flow induced pulsations» or «singing»).

In order to overcome this problem, it is known to manufacture flexible pipes without internal carcass. These pipes have a smooth surface («smooth bore»), but are subject to collapse in case of depressurization.

Another solution to this problem is disclosed in WO 2014/135906. In this document, the flexible pipe comprises a carcass in which the helicoidal gap present between the different turns of the carcass is closed by a S-shaped profiled tape, inserted into a profiled interlocked tape.

Such a carcass is efficient for reducing the flow induced vibrations. It is nevertheless quite complex to manufacture.

Indeed, two different profiler apparatuses are needed to profile on the one hand, the first tape forming the interlocked carcass, and on the other hand, the tape forming the S-shaped insert closing the gap of the interlocked carcass.

After profiling each tape separately, a joining apparatus is used to form a joint profiled strip which is wounded helicoidally to form the tubular reinforcement.

The machine used to form the carcass is therefore bulky and complex to use. In particular, the joining of the first profiled tape with the second profiled tape must be carried out with great precision, which requires a fine tuning of the machine.

SUMMARY OF THE INVENTION

One aim of the invention is therefore to obtain a machine able to form a tubular reinforcement for a pipe, in which the risk of vibrations and/or even of pulsations is limited, the machine being compact and easy to operate.

To this aim, the subject-matter of the invention is a machine as described above, characterized in that the profiler apparatus comprises:

an intermediate joining stage able to receive the second tape as a flat tape from the second feeder and able to join the pre-formed first tape and the flat second tape; and

at least a downstream profiling stage configured to jointly profile the first tape and the second tape received from the intermediate joining stage and form a combined profiled strip.

The machine according to the invention may comprise one or more of the following features, taken solely or according to any technical feasible combination:

the intermediate joining stage comprises at least a redirecting first roller for redirection of the second tape from the second feeder to the at least one downstream profiling stage, the second tape remaining a flat tape, the intermediate joining stage comprising a second roller for supporting the pre-profiled first tape;

each profiling stage has at least two opposite rollers defining between them a profiling interspace;

at least a downstream profiling stage has a profiling interspace comprising at least a region for joint deformation of the first tape and of the second tape and at least a region for the deformation of only the first tape, without deformation of the second tape;

the profiling interspace of the at least a downstream profiling stage comprises at least a region for maintaining the shape of a region of the second tape;

the shape maintaining region is delimited, in cross section in a plane containing rotation axes of the opposite rollers, by opposite flat zones, the second tape remaining flat in the shape maintaining region;

at least one of the opposite rollers defines a lateral deforming surface for bending an edge of the first tape;

the second feeder comprises a second tape unwinder onto which the flat second tape is rolled, at least one second tape guiding roller for directing the second tape issuing from the second tape unwinder towards the intermediate joining stage;

the second feeder comprises a brake, advantageously interposed between the second tape unwinder and the intermediate joining stage, to control the feeding speed of the second tape in the intermediate joining stage;

the second feeder comprises a pair of opposed alignment rollers to guide the second tape to the intermediate joining stage with a predefined feeding direction;

the machine comprises a winding apparatus able to helicoidally wind the combined profiled strip on a cylindrical outer surface to form the tubular reinforcement;

the winding apparatus comprises a rotary support mounted rotatable around a winding axis defined by the cylindrical outer surface, the rotating table bearing the first feeder, the second feeder, and the profiler apparatus.

The invention also concerns a method for forming a tubular reinforcement for a pipe comprising the following steps:

unwinding a first tape from a first feeder;

feeding the first tape from the first feeder to at least an upstream profiling stage of a profiler apparatus to form a pre-profiled first tape;

unwinding a second tape from a second feeder, the second tape being a flat tape; characterized by:

feeding the second tape as a flat tape from the second feeder in an intermediate joining stage of the profiler apparatus and joining the pre-formed first tape and the flat second tape in the intermediate joining stage;

jointly profiling the first tape and the second tape received from the intermediate joining stage in at least a downstream profiling stage to form a combined profiled strip.

The method according to the invention may comprise one or more of the following features, taken solely or according to any technical feasible combination:

each profiling stage has at least two opposite rollers defining between them a profiling interspace,

the joint profiling of the first tape and the second tape in at least a downstream profiling stage comprises jointly deforming the first tape and of the second tape in at least a region for joint deformation in the interspace and deforming only the first tape without deformation of the second tape in at least a region for the deformation of only the first tape in the interspace;

the method comprises helicoidally winding the combined profiled strip on a cylindrical outer surface to form the tubular reinforcement.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood based on the following description, given solely as an example, and made in reference to the appended drawings, in which:

FIG. **1** is a partly cutaway perspective view of a central segment of a first flexible pipe made using a method according to the invention;

FIG. **2** is a partial sectional view along an axial midplane of a detail of the pipe of FIG. **1**, illustrating the carcass and the insert positioned in the gap of the carcass;

FIG. **3** is a view of a detail of FIG. **2**, illustrating a lazy-S-shaped section of the insert;

FIG. **4** is a front schematic view of a first machine for forming the carcass of FIG. **2** FIG. **2**;

FIGS. **5** to **7** are cross-sectional views of profiling rollers of successive upstream profiling stages of a first tape in the machine of FIG. **3**;

FIG. **8** is a view similar to FIG. **5** of the intermediate joining stage of the machine of FIG. **3** for joining the pre-profiled first tape and a second flat tape;

FIGS. **9** to **10** are views similar to FIG. **5** of profiling rollers of successive downstream joint profiling stages of the first tape and of the second tape in the machine of FIG. **3**;

FIG. **11** is a view similar to FIG. **3**, illustrating an alternate L-shaped section of the insert.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

In all the following, the terms of «outer» and «inner» are generally understood radially with respect to an axis A-A' of the pipe, the term of «outer» being understood as relatively further away radially from the A-A' and the term of «inner» extending as relatively and radially closer to the A-A' axis of the pipe.

A first flexible pipe **10** is partly illustrated by FIG. **1**.

The flexible pipe **10** includes a central segment **12**. It includes, at each of the axial ends of the central segments **12**, an end-piece (not visible).

With reference to FIG. **1**, the pipe **10** delimits a central passage **16** for circulation of a fluid, advantageously a petroleum fluid. The central passage **16** extends along an axis A-A', between the upstream end and the downstream end of the pipe **10**.

The central passage diameter advantageously ranges from 15 cm to 60 cm.

The flexible pipe **10** is intended to be positioned through a body of water (not shown) in an installation for exploiting fluid, in particular hydrocarbons.

The body of water is for instance a lake, a sea, or an ocean. The depth of the body of water perpendicular to the surface facility is typically between 15 m and 3000 m.

The surface facility is for example a surface base, a semisubmersible platform, a floating vertical column, an offloading buoy or a vessel such as an FPSO («Floating Production, Storage and Offloading), or a FLNG («Floating Liquefied Natural Gas).

Alternatively, the surface facility is a jacket-like fixed rigid structure or an oscillating structure secured downward of the sea, e.g. a TLP («Tension Leg Platform»).

The flexible pipe **10** is preferably an «unbonded» pipe. At least two adjacent layers of the flexible pipe **10** are free to move longitudinally with respect to each other during flexure of the pipe **10**.

Advantageously, all the layers of the flexible pipe **10** are free to move relatively to each other. Such a pipe is for example described in the standardized documents API **17**J (Specification for Unbonded Flexible Pipe, 4th edition—May 2014) and API RP **17**B (Recommended Practice for Flexible Pipe, 5th edition—March 2014) established by the American Petroleum Institute.

As illustrated by FIG. **1**, the pipe **10** delimits a plurality of concentric layers around the axis A-A', which continuously extends along the central segment **12** as far as the end pieces located at the ends of the pipe.

According to the invention, the pipe **10** includes at least one first tubular sheath **20** based on a polymeric material advantageously making up a pressure sheath.

The pipe **10** further includes at least one layer of tensile armors **24**, **25** positioned exteriorly with respect to the first sheath **20** forming a pressure sheath.

The pipe **10** further includes an internal carcass **26** positioned inside the pressure sheath **20**, optionally a pressure vault **27** inserted between the pressure sheath **20** and the layer(s) of tensile armors **24**, **25**, and an external sheath **30**, intended for protecting the pipe **10**.

According to the invention, the pipe **10** further includes an insert **28** having a lazy-S-shaped cross-section, the insert **28** being positioned so as to be interiorly supported on the internal carcass **26**. In a variant, the insert **28** has a T-shape or a L-shape (see FIG. **11**).

The internal carcass **26** and the insert **28** jointly form a tubular reinforcement **29** of the pipe **10**.

In a known way, the pressure sheath **20** is intended to tightly confine the fluid transported in the passage **16**. It is formed of a polymeric material, for example based on a polyolefin such as polyethylene, based on a polyamide such as PA11 or PA12, or based on a fluorinated polymer such as polyvinylidene fluoride (PVDF).

The thickness of the pressure sheath **20** is for example comprised between 5 mm and 20 mm.

As illustrated by FIG. **2**, the carcass **26** is formed here with a first helicoidally wound profiled metal tape **31**. The successive turns of the tape **31** are stapled with each other.

The tape **31** has a thickness advantageously comprised between 0.8 mm and 3.5 mm and a width advantageously comprised between 40 mm and 140 mm.

The main function of the carcass **26** is to absorb the squeezing radial forces.

The carcass **26** is positioned inside the pressure sheath **20**. It is able to come into contact with the fluid circulating in the pressure sheath **20**.

The helicoidal winding of the first profiled tape **31** forming the carcass **26** is with a short pitch, i.e. it has a helix angle with an absolute value close to 90°, typically comprised between 75° and 90°.

The first tape **31** has two edges longitudinally bent back on a central region. It defines a plurality of stapled turns with a closed and flattened S-shaped section, as illustrated by FIG. **2**. The first tape **31** has a substantially constant thickness e1.

The closed S-shaped section of each turn of the carcass **26** successively comprises, parallel to the axis A-A' from right to left in FIG. **2**, an inner U-shaped portion **32**, a tilted intermediate portion **34** and an outer U-shaped portion **36**, in vicinity to its free end, a supporting wave **38**, commonly referred to with the term of «nipple».

The inner portion **32** of each turn of the first tape **31** is bent back towards the intermediate portion **34** away from the central axis A-A', exteriorly with respect to the tilted portion **34**. It defines a U-section extending parallel to the A-A' axis and opening facing the tilted portion **34**.

The distance between the two legs of the U is generally twice the thickness of the tape **31**, but could be more. The length of the U legs is generally from 6 mm to 12 mm.

The angle of the titled intermediate portion **34** is generally from 10° to 20° in reference to a radial axis perpendicular to axis A-A'.

The outer portion **36** of an adjacent turn is partly engaged into the inner portion **32**, the supporting wave **38** being inserted between the branches of the U.

The inner portion **32** defines an inner surface **39** located on a cylindrical envelope of axis A-A'.

The outer portion **36** also defines a U section extending parallel to the A-A' axis and opening facing the tilted portion **34**.

The outer portion **36** of each turn is bent back towards the intermediate portion **34**, towards the central axis A-A', interiorly with respect to the tilted portion **34**. The outer portion **36** and the supporting wave **38** of the section are received into the inner portion **32** of an adjacent section, and partly covering outwards the inner portion **32** of the adjacent section.

The width and the length of the supporting wave **38** is generally from 1 mm to 5 mm

For each turn, the intermediate portion **34**, the outer portion **36** and the inner portion **32** of an adjacent section delimit an inner gap **40**, partly or completely defining the axial play of the carcass **26**.

The gap **40** radially opens towards the central axis A-A'. For each turn, it opens interiorly towards the axis A-A' between the inner surfaces **39** of the inner portions **32** of two adjacent turns.

Exteriorly, the gap **40** is closed by the outer portion **36** and laterally by the intermediate portion **34** of a turn and by the inner portion **32** of an adjacent turn.

The gap **40** thus continuously extends as a helix of axis A-A', according to a pitch P1 along the carcass **26**.

Each turn of the carcass **26** has a width advantageously comprised between 25 mm and 100 mm.

The carcass **26** has, between each pair of stapled turns, a first axial play defined by the relative sliding axial travel of the outer portion **36** of a turn in the inner portion **32** of an adjacent turn into which it is engaged.

The insert **28** is partly positioned in the gap **40** and closes the gap **40** towards the axis A-A'.

The insert **28** thus advantageously has a helicoidal shape of axis A-A', with a pitch P1 similar to the pitch of the gap **40**.

As illustrated by FIG. **3**, the insert **28** has a section, taken in a axial midplane, of a lazy-S-shape.

It includes an axial outer region **42**, a radial intermediate region **44** and an axial inner region **46** protruding from the intermediate region **44**, axially opposite to and radially away from the axial outer region **42**,

The axial inner region **46** at least partly closes the gap **40**. Advantageously, the axial inner region **46** completely closes the gap **40**.

According to the invention, the insert **28** is made in a single piece by bending a second tape **48**.

The second tape **48** is preferably metal. It advantageously has a constant thickness e2. The thickness e2 of the second tape **48** is preferably less than the thickness e1 of the first tape **31**. The thickness e2 of the second tape **48** is advantageously comprised between one-third and two-thirds of the thickness e1 of the first tape **31**.

The thickness e2 is for example comprised between 0.5 mm and 2 mm, in particular between 0.8 mm and 1.5 mm.

Such a thickness guarantees sufficient stiffness, while limiting the risk of disorganization when a probe in introduced into the central passage **16** ("pigging" operations).

In the example illustrated in FIG. **2** and FIG. **3**, the outer region **42** extends over a cylindrical envelope of central axis A-A'.

The outer region **42** is clamped between the outer branch of the U of the outer portion **36** of a turn of the carcass **26** and the outer branch of the U of the inner portion **32** of an adjacent turn of the carcass **26**. It is applied against the inner surface of the outer portion **36**.

As illustrated by FIG. **3**, the intermediate region **44** comprises a curved connecting outer segment **50** with the outer region **42**, an intermediate segment **52** with a linear section, and a curved inner segment **54** connected with the inner region **46**.

The outer segment **50** has a convexity curvature directed outwards. The radius of curvature of the outer segment **50** is advantageously greater than the thickness e2 of the second tape **48**.

The intermediate segment **52** extended in a tilted way with respect to an axis perpendicular to the central axis A-A', while being axially located away from the outer segment **42** and from the inner segment **46**.

The inner segment **54** has a curvature of convexity which is directed inwards, opposite to the convexity of the curvature of the outer segment **50**. It has a radius of curvature greater than the radius of curvature of the outer segment **50**.

The intermediate region **44** is applied on an inner surface of the intermediate portion **34**. It has a shape complementary to the shape of the intermediate portion **34**.

The intermediate region **44** is positioned in the gap **40** between the intermediate portion **34** and the outer portion **36** of a turn of the carcass **26**, and the inner portion **32** of an adjacent turn of the carcass **26**.

The outer region **42** axially protrudes from the outer segment **50** of the intermediate region **44**.

The inner region **46** also extends axially along the axis A-A', over a cylindrical envelope of A-A' or with an angle of less than 10° with respect to this envelope.

Preferably, the inner region **46** is elastically urged towards a tilted position with respect to the cylindrical envelope of axis A-A', directed outwards, as illustrated in thin lines in FIG. **3**, when it is positioned on a cylindrical envelope of axis A-A'.

The width L1 of the inner region **46**, taken along the axis A-A' is greater than the width L2 of the outer region **42**, taken along the axis A-A'. In the variant of FIG. **11** in which the insert **28** has a L-shape, the insert **18** does not comprise an outer region **42**.

The inner region **46** axially extends opposite to the outer region **42** with respect to the intermediate region **44**, and radially away from the latter.

It protrudes from the inner segment **54** of the intermediate region **44**.

With reference to FIG. **2**, the inner region **46** of each turn of the insert **28** includes a first axial segment **56** applied on the inner surface **39** of the inner portion **32** of a turn of the carcass **26**, an axial intermediate segment **58** closing inwards the gap **40** delimited by the inner portion **32**, and a second axial segment **60** applied on an inner surface of the inner region **46** of an adjacent turn of the insert **28**, at the first axial segment **56** of this inner region **46**.

The inner region **46** of each turn of the insert **28** is advantageously maintained applied against the inner surface of the inner region **46** of a turn of the insert **28**, by elastically urging the inner region **46** outwards.

Thus, the successive turns of the insert **28** overlap each other by their inner regions **46**, in order to close the gap **40** inwards.

The overlapping width of each inner region **46**, when the carcass **26** occupies a non-deformed linear configuration is greater than the axial play of the carcass **26**.

With reference to FIG. **1**, the pressure vault **27** is intended to absorb the forces related to the pressure prevailing inside the pressure sheath **20**. For example it is formed with a helicoidally wound metal profiled wire around the sheath **20**. The profiled wire generally has a complex geometry, in particular Z-shaped, T-shaped, U-shaped, K-shaped, X-shaped or I-shaped.

The pressure vault **27** is helicoidally wound with a short pitch around the pressure sheath **20**, i.e. with a helix angle of an absolute value close to 90°, typically comprised between 75° and 90°.

The flexible pipe **10** according to the invention comprises at least one layer of armors **24**, **25** formed with a helicoidal winding of at least one elongated armor element **63**.

In the example illustrated in FIG. **1**, the flexible pipe **10** includes a plurality of layers of armors **24**, **25**, in particular an inner layer of armors **24**, applied on the pressure vault **27** and an outer layer of armors **25** around which is positioned the outer sheath **30**.

Each layer of armors **24**, **25** includes longitudinal armor elements **63** wound with a long pitch around the axis A-A' of the pipe.

By "wound with a long pitch", is meant that the absolute value of the helix angle is less than 60°, and is typically comprised between 25° and 55°.

The armor elements **63** of a first layer **24** are generally wound according to an opposite angle with respect to the armor elements **63** of a second layer **25**. Thus, if the winding angle of the armor elements **63** of the first layer **24** is equal to +a, a being comprised between 25° and 55°, the winding angle of the armor elements **63** of the second layer of armors **25** positioned in contact with the first layer of armors **24** is for example equal to $-\alpha°$.

The armor elements **63** are for example formed with metal wires, in particular steel wires, or with strips in composite material, for example strips reinforced with carbon fibers.

The external sheath **30** is intended to prevent permeation of fluid from the outside of the flexible pipe **10** towards the inside. It is advantageously made in a polymeric material, in particular based on a polyolefin, such as polyethylene, or on the basis of a polyamide, such as PA11 or PA12.

The thickness of the external sheath **30** is for example comprised between 5 mm and 15 mm.

The tubular reinforcement **29** comprising the carcass **26** and the insert **28** is manufactured in a machine **100** according to the invention, shown in FIGS. **4** to **10**.

The machine **100** comprises a central mandrel **102** defining an outer tubular surface **104** for supporting and shaping the tubular reinforcement **29**. It comprises a rotary support **106** mounted rotary around a winding axis E-E' of the central mandrel **102**, and a profiling device **108** borne by the rotary support **106** to be jointly moved in rotation with the rotary support **106**.

The profiling device **108** comprises a profiler apparatus **110**, a first feeder **112** for feeding the flat first tape **31** to the profiling apparatus **110** to form a pre-profiled first tape **31**, and a second feeder **114** for feeding the flat second tape **48** to the profiler apparatus **110** and have the second tape **48** being jointly profiled with the pre-profiled first tape **31** to form a combined profiled strip **196** to be wound on the outer tubular surface **104**.

The profiling device **108** also comprises a locking device **115** able to close and interlock the successive turns of the combined profiled strip **196**.

In this example, the central mandrel **102** directly defines the outer surface **104** around which the tubular reinforcement **29** is wound.

In this example, the central mandrel **102** is formed by a metal tube defining the outer surface **104**.

In a variant (not shown), the outer surface **104** is defined onto a tubular sheath of the pipe.

The rotary support **106** is here formed by a circular table. The rotary support **106** defines a front face **116** and a back face **118** opposed to the front face **116**. It delimits, between the front face **116** and the back face **118**, a central through passage **120** through which the mandrel **102** extends.

The rotary support **106** is able to rotate with regards to the outer surface **104** around the winding axis E-E', to allow the winding of successive turns of the tubular reinforcement **29** with a helical shape. The tubular reinforcement formed on the outer surface **104** is able to slide on the outer surface **104** along the axis E-E'.

As indicated above, the profiling device **108** is borne by the rotary support **106** to be rotated jointly with the rotary support **106**. The profiler apparatus **110** comprises at least one, preferentially a plurality of upstream profiling stages **122**A to **122**G, at least an intermediate joining stage **124**, and at least one, preferentially a plurality of joint profiling stages **126**A to **126**C for jointly profiling the first tape **31** and the second tape **48**.

The profiler apparatus **110** further comprises a common support body **128** bearing the upstream profiling stages **122**A to **122**G, the joining stage **124** and the downstream profiling stages **126**A to **126**C. It comprises a displacement device **129** of the common support body **128** on the rotary support **106**.

The upstream profiling stages **122**A to **122**G, the joining stage **124**, and the downstream profiling stages **126**A to **126**C, each comprise a pair of opposite rollers **130**, **132** defining between them an profiling interspace **134**.

The rollers **130**, **132** are rotatably mounted around rotation axes parallel to each other and parallel to the winding axis E-E'. The rollers **130**, **132** respectively define rows on the common support body **128**. The interspaces **134** between the respective rollers **130**, **132** are preferably aligned along a profiling axis F-F' perpendicular to the winding axis E-E'.

The rollers **130**, **132** advantageously have an average diameter ranging from 10 cm to 30 cm.

The upstream profiling stages **122**A to **122**G are configured to receive the flat first tape **31** from the first feeder **112** and to form a pre-profiled first tape **31** by deformation of at least a region of the flat first tape **31** to generate a cross section distinct from the cross section of the flat first tape **31**.

They comprise at least one stage **122**A, **122**B for forming the intermediate portion **34** of the first tape **31**, at least a stage **122**C for forming the supporting wave **38** and several stages for pre-bending the edges of the first tape **31** to form the inner portion **32** and the outer portion **36** of the first tape **31**.

The stage **1228** for forming the intermediate portion **34** of the first tape **31** is shown in FIG. **5**. In cross section in a plane P joining the rotation axes of the rollers **130**, **132**, the first roller **130** defines at least an inclined step **138** between two flat zones **139** parallel to the rotation axis.

In this example, the roller comprises two disc **136**A, **136**B defining the step **138**, and a first lateral disc **136**C for positioning a first lateral edge of the first tape **31** and for laterally closing the interspace **134** on a first side.

In the plane P, the second roller **132** also defines a step **142** between two flat zones **143** parallel to the rotation axis. Step **142** is positioned facing and apart from step **138**. The flat zones **139**, **143**, are facing each other, apart from each other.

In this example, the roller **132** comprises two discs **140**A, **140**B defining the step **142** and a lateral disc **140**C for positioning a second lateral edge of the first tape **31** and for laterally closing the interspace **134** on a second side.

The interspace **134**, taken in section in a plane containing the axis of rotations of both rollers **130**, **132** comprises a first and second flat regions **144**, **148** defined between respective flat zones **139**, **143**, and between the flat regions **144**, **148**, an intermediary stepped region **146** defined between steps **138**, **142**.

In a further upstream preforming stage **122**C, shown in FIG. **6**, the roller **130** defines a circumferential groove **150** to form the supporting wave **38**. The groove **150** is here made on a side of disc **136**B.

The interspace **134** also comprises on a side of the rollers **130**, **132** an inclined region **152** to initiate the bending of the first tape **31** along the first lateral edge.

The inclined region **152** is here defined between a protruding zone of the first roller **130** and a corresponding recessed zone of the second roller **132**.

The stage **122**C does not comprise lateral discs **136**C, **140**C.

In a further upstream preforming stage **122**F, the first roller **130** comprises a lateral annular protrusion **154** for continuing the bending of the first lateral edge of the first tape **31**. The protrusion **152** has a curved concave surface extending along a curved convex lateral surface of the second roller **132**. The protrusion **154** is here formed on disc **136**A.

The second roller **132** also comprises a lateral annular protrusion **156** for partially deforming the second lateral edge of the first tape **31** comprising the supporting wave **38**. The protrusion **156** has a curved concave surface extending along a curved convex lateral surface of the first roller **130**. The protrusion **156** is here formed on disc **140**B.

The curved concave surfaces are able to bend the sides of the first tape **31** with an angle greater than 45°, in particular greater than 80° with regards to the flat regions **144** of the interspace **134**.

As shown in FIG. **8**, in the intermediate joining stage **124**, the first roller **130** is a guiding roller configured for redirecting the second tape **48** from the second feeder **114** to the downstream profiling stage **126**A to **126**C, the second tape **48** remaining a flat tape.

The first roller **130** defines, in cross section in the plane P, a flat zone **158** for deflection without deformation of the second tape **48**. The flat zone **158** is advantageously delimited on one side by a positioning protrusion for abutting an edge of the flat second tape **48**.

The flat zone **158** is able to redirect the second tape **48** from the second feeder **114** into a direction parallel to the profiling axis F-F'. The second tape **48** remains flat when it is deflected by the first roller **130**. It has the same cross section before and after passing the first roller **130**.

Advantageously, the first roller **130** is mounted freely rotatable around its axis, without being driven.

In the intermediate joining stage **124**, the second roller **132** has a shape similar to the second roller of upstream preforming stage **122**F to support the preformed first tape **31**, facing the flat zone **158**, in contact with the second tape **48** or at a short distance of the second tape **48**, for example at a distance smaller than the thickness of the second tape **48**.

The preformed first tape **31** and second tape **48** are therefore joined, by being placed with their longitudinal local axis parallel to each other. The preformed first tape **31** and second tape **48** are in the vicinity of one another, preferably in contact with one another.

The preformed first tape **31** is also in contact with the second roller **132**. It advantageously lays on the second roller **132**, such that the second roller **132** prevents the preformed first tape **31** from falling down under the effect of gravity.

The interspace **134** locally has a width, taken perpendicular to the rotation axes of the rollers **130**, **132** greater than the sum of the thickness of the first tape and of the thickness of the second tape **48**.

In the downstream joint profiling stages **126**A, **126**B, the successive rollers **130**, **132** are able to jointly profile the first tape **31** and the second tape **48** such that the cross section of each of the first tape **31** and of the second tape **48** varies after passing the rollers **130**, **132**.

In the example of FIGS. **9** and **10**, the first roller **130** again comprises a step **138**, which is facing and apart the step **142** defined on the second roller **132**. The step **138** is able to profile the second tape **48**, to form an intermediate region **44** having a shape complementary to the shape of intermediate portion **34** of the first tape **31**.

The first roller **130** also defines a lateral bending surface **160** delimiting a lateral groove **162** for continuing the bending the outer portion **36** of the first tape **31** comprising the supporting wave **38**, without jointly bending the second tape **48**.

The lateral bending surface **160** is here delimited on a disc **1368** of the first roller **130**. The groove **162** is delimited between the disc **136**A and the disc **136**B of the first roller **130**.

Similarly, the second roller **132** delimits a lateral bending surface **164** for bending the inner portion **32** of the first tape **31**, and a groove **166** for receiving the bent part of the inner portion **32**.

The protrusion **138** is here formed on the first disk **136**A. The lateral surface **164** is delimited on a lateral disc **140**B of the second roller **132**. The groove **166** is delimited between a first disc **140**A and the disc **140**B of the second roller **132**.

Thus, the interspace **134** comprises a central region **168** in which a joint deformation of the first tape **31** and of the second tape **48** is carried out, in particular to form the tilted intermediate portion **34** of the first tape and the intermediate region **44** of the second tape **48**.

The interspace **134** also comprises two regions **170** for deforming only the first tape **31** delimited by the grooves **162**, **166**, and a region **172** for maintaining the flat shape of the second tape **48**, to form the inner region **46** of the second tape **48**.

The first feeder **112** is configured to feed the first tape **31** to the upstream profiling stage **122**A in order to pre-profile the first tape **31**.

It comprises a first unwinder **180** around which the flat first tape **31** is rolled. The first unwinder **180** is here fixed on the opposite face **118** of the rotary support **106**.

The first feeder **112** also comprises first guide rollers **182**A, **182**B, **182**C which are able to guide the first tape **31** from the unwinder **180** and to twist it to align it with the profiling axis F-F' when entering the upstream profiling stage **122**A.

The second feeder **114** comprises a second unwinder **184** and second guide rollers **186**A, **186**B, to feed the second tape **48** in the intermediate joining stage **124**, as a flat tape.

The second guide rollers **186**A, **186**B are configured to change the direction of the local longitudinal axis of the second tape **48**, without modifying its cross section, i.e. maintaining the second tape **48** as a flat tape.

In the example of FIG. **4**, the second feeder **114** further comprises a brake **187** to control the feeding speed of the second tape **48**, and a pair **188** of aligning rollers, able to insert the flat second tape **48** into the intermediate joining stage **124**, in a predetermined feeding direction G-G', non-parallel to the profiling axis B-B', in particular perpendicular to the profiling axis F-F'. The predetermined feeding direction G-G' makes an angle comprised between 45° and 135°, in particular 90° with the profiling axis F-F'.

The support body **128** holds the successive rollers **130**, **132** of each stage **122**A to **122**G, **124**, **126**A to **126**C in succession along the profiling axis F-F'.

The displacing device **129** comprises at least a transverse displacer **130** able to move the support body **128** and the profiling axis F-F' transversely with regard to the mandrel axis E-E', and an axial displacer **192** able to move the support body **128** along the profiling axis F-F'.

A method for manufacturing a tubular reinforcement **29** according to the invention will be now described.

When carrying out the method, the first feeder **112** is activated to unwind the flat first tape **31**, to feed it to the upstream profiling stages **122**A to **122**G.

The first tape **31** is guided by the guiding rollers **182**A, **182**B, **182**C, is advantageously twisted and aligned to make it parallel to the profiling axis F-F'.

Then, the first tape **31** runs through the successive upstream profiling stages **122**A to **122**G. It is progressively profiled in the successive interspaces **134** between the rollers **130**, **132** of the successive upstream profiling stages **122**A to **122**G.

As shown in FIG. **5**, in stages **122**A to **122**B, the first tape **31** is first bent in the stepped region **146** to form the intermediate portion **34** of the profiled first tape **31**, the other portions of the first tape **31** remaining flat.

Then, as shown in FIG. **6**, the supporting wave **38** is formed into the groove **150** of stage **122**C. In the subsequent upstream profiling stages **122**D to **122**F, the edges of the first tape **31** are then progressively bent, as shown in FIG. **7**.

In FIG. **7**, the lateral edges of the first tape **31** are now partially bent to define the inner portion **32** and the outer portion **36** with an open J-shape. The first tape **31** is therefore pre-profiled when it enters the intermediate joining stage **124**.

Simultaneously, the second feeder **114** is activated to unwind the second tape **48** from the second unwinder **184**. The second tape **48** runs along the rollers **186**A, **186**B, **186**C to reach the brake **187** and the aligning rollers **188**. It is then aligned along a feeding direction G-G' with a predetermined angle with the profiling axis F-F'. It remains a flat tape.

In the joining stage **124**, the second tape **48** is fed as a flat tape and is aligned by contact with the flat zone **158** of the first roller **130** to be parallel to the profiling axis F-F'.

The pre-profiled first tape **31** is just supported on the second roller **132** to be placed facing the second tape **48**.

The longitudinal local axis of the pre-profiled first tape **31** and of the flat second tape **48** are thus placed parallel to each other. The pre-profiled first tape **31** and the flat second tape **48** are in the vicinity of one another, preferably in contact with one another.

Then, in the downstream profiling stages **126**A to **126**C, the first tape **31** and the second tape **48** are jointly profiled, in the central region **168** of the interspace **134** between the rollers **130**, **132**. The intermediate region **44** of the second tape **48** and the intermediate portion **34** of the first tape **31**, as well as the axial outer region of the first tape **36** and a segment of the outer portion **36** of the first tape **31** are profiled with complementary shapes, in contact with one another.

Moreover, in regions **170** of the interspace **134**, in particular in the grooves **162**, **166**, the edges of the first tape **31** are deformed without deformation of the second tape **48**, to adopt an open U-shape.

Finally, in region **172**, the second tape **48** is kept flat to form the flat inner region **46** of the insert **28**.

The combined profiled strip **196** which is obtained at the outlet of the profiler apparatus **110** is then fed to the outer surface **104** of the mandrel **102**. The rotary support **106** is continuously rotated around the axis E-E' while the mandrel **102** is driven in translation along the axis E-E'.

The combined profiled strip **196** is then wound helicoidally around the surface **104**, to form successive turns, with the desired pitch.

Simultaneously, the partly open outer portion **36** of each turn of the first tape **31** is inserted into the inner portion **32** of an adjacent turn, the outer region of the insert **28** being inserted between the outer portion **36** of the turn and the inner portion of the adjacent turn.

The inner region **46** of each turn of the second tape **48** is applied on the inner region **46** of an adjacent turn to close the gap **40** being formed between the successive turns of the first tape **31**.

Radial applying members of the locking device **115** are then applied on the outside of the combined profile strip **196** to close and interlock the carcass **26** and the insert **28**.

Once the tubular reinforcement **29** has been manufactured, the internal sheath **20** is formed around the carcass **26**, for example by extrusion. The pressure vault **27** and the armor layers **24**, **25** are then wound around the internal sheath **20**. The external sheath **30** is then advantageously formed by extrusion while being positioned outside the layers of armor **24**, **25**.

Thanks to the machine **100** according to the invention, the method of manufacturing the tubular reinforcement **29** is simple to operate. The joint deformation of the first tape **31** and of the second tape **48** ensures a perfect fit between the tapes **31**, **48** before the carcass **26** is interlocked. Moreover, the feeding of the second tape **48** as a flat tape in the joining stage **124** is simple to operate, and does not require a bulky arrangement.

The first feeder **112** for the first tape **31**, the second feeder **114** for the second tape **48** and the profiler apparatus **110** are all fitted on the same rotary support **106**, which simplifies the equipment needed to form the carcass **26** and reduces its bulkiness. The machine **100** is therefore particularly suitable for forming the carcass.

The second tape **48** is introduced very easily in the machine **100** by using a simple deflecting roller **130** of the joining stage **124**. Machines used to profile only a first tape **31** can therefore easily be retrofitted to include a joining stage **124** for the second tape **48**.

In a variant, a tubular reinforcement **29** is formed on an outer surface **104** delimited on an internal sheath of a pipe.

The invention claimed is:

1. A pipe tubular reinforcement forming machine, comprising:

- a first feeder, configured to unwind a first tape;
- a profiler comprising at least one upstream profiling stage configured to receive the first tape from the first feeder and configured to profile the first tape to form a pre-profiled first tape;
- a second feeder, configured to unwind a second tape, the second tape being a flat tape;
- an intermediate joining stage configured to receive the second tape as a flat tape from the second feeder and configured to join the pre-profiled first tape and the flat second tape; and
- at least one downstream profiling stage configured to jointly profile the first tape and the second tape received from the intermediate joining stage and to form a combined profiled strip,
- wherein the machine is without a profiler within the second feeder or between the second feeder and the intermediate joining stage such that the transverse section of the second tape remains constant in the second feeder, up to the intermediate joining stage,
- the at least one upstream profiling stage and the at least one downstream profiling stage each have at least two opposite rollers defining between them a profiling interspace, and
- the at least one downstream profiling stage has a profiling interspace that comprises,
  - at least a first region configured to jointly deform the first tape and the second tape, and
  - at least a second region configured to deform only the first tape, without deforming the second tape.

2. The machine according to claim **1**, wherein the intermediate joining stage comprises at least a redirecting first roller configured to redirect the second tape from the second feeder to the at least one downstream profiling stage, the second tape remaining a flat tape, the intermediate joining stage comprising a second roller configured to support the pre-profiled first tape.

3. The machine according to claim **1**, wherein the profiling interspace of the at least one downstream profiling stage comprises at least a third region configured to maintain the shape of a fourth region of the second tape.

4. The machine according to claim **3**, wherein, in cross section in a plane containing rotation axes of the at least two opposite rollers, the third region is delimited by opposite flat zones, the second tape remaining flat in the third region.

5. The machine according to claim **1**, wherein at least one of the at least two opposite rollers defines a lateral deforming surface for bending an edge of the first tape.

6. The machine according to claim **1**, wherein the second feeder comprises a second tape unwinder, the flat second tape being rolled on the second tape unwinder, the machine comprising at least one second tape guiding roller configured to direct the second tape issuing from the second tape unwinder towards the intermediate joining stage.

7. The machine according to claim **6**, wherein the second feeder comprises a brake to control the feeding speed of the second tape in the intermediate joining stage.

8. The machine according to claim **7**, wherein the brake is interposed between the second tape unwinder and the intermediate joining stage.

9. The machine according to claim **6**, wherein the second feeder comprises a pair of opposed alignment rollers to guide the second tape to the intermediate joining stage with a predefined feeding direction.

10. The machine according to claim **1**, comprising a winder configured to helicoidally wind the combined profiled strip on a cylindrical outer surface to form the tubular reinforcement.

11. The machine according to claim **10**, wherein the winder comprises a rotary support mounted rotatable around a winding axis defined by the cylindrical outer surface, the rotating table bearing the first feeder, the second feeder, and the profiler.

12. A pipe tubular reinforcement forming method comprising:

unwinding a first tape from a first feeder;

feeding the first tape from the first feeder to at least one upstream profiling stage of a profiler to form a pre-profiled first tape;

unwinding a second tape from a second feeder, the second tape being a flat tape;

feeding the second tape as a flat tape from the second feeder, without profiling, to an intermediate joining stage of the profiler and joining the pre-profiled first tape and the flat second tape in the intermediate joining stage;

jointly profiling the first tape and the second tape received from the intermediate joining stage in at least one downstream profiling stage to form a combined profiled strip,

the at least one upstream profiling stage and the at least one downstream profiling stage each have at least two opposite rollers defining between them a profiling interspace, and

the at least one downstream profiling stage has a profiling interspace that comprises,

at least a first region configured to jointly deform the first tape and the second tape, and

at least a second region configured to deform only the first tape, without deforming the second tape.

13. The method according to claim 12, wherein the at least one upstream profiling stage and the at least one downstream profiling stage each has at least two opposite rollers defining between them a profiling interspace,

the joint profiling of the first tape and the second tape in the at least one downstream profiling stage comprises jointly deforming the first tape and of the second tape in at least a first region configured to jointly deform the first tape and the second tape in the interspace and deforming only the first tape without deformation of the second tape in at least a second region configured to deform only the first tape in the interspace.

14. The method according to claim 12, comprising helicoidally winding the combined profiled strip on a cylindrical outer surface to form the tubular reinforcement.

15. A pipe tubular reinforcement forming machine, comprising:

a first feeder, configured to unwind a first tape;

a profiler comprising at least an upstream profiling stage configured to receive the first tape from the first feeder and configured to profile the first tape to form a pre-profiled first tape;

a second feeder, configured to unwind a second tape, the second tape being a flat tape;

an intermediate joining stage configured to receive the second tape as a flat tape from the second feeder and configured to join the pre-profiled first tape and the flat second tape; and

at least a downstream profiling stage configured to jointly profile the first tape and the second tape received from the intermediate joining stage and to form a combined profiled strip,

wherein the second feeder comprises a second unwinder and a second guide roller to feed the second tape in the intermediate joining stage as a flat tape, the second guide roller being configured to change direction of the second tape's local longitudinal axis, without modifying its cross section.

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