

Title: Production-optimized process for producing a multilayer pipe

5 The present invention relates to a production-optimized process for producing a multilayer pipe. Multilayer pipes are preferably used whenever demanding corrosion or abrasion requirements have to be met.

10 Corrosion-resistant pressure vessels or pressure lines can be produced at lower cost by using multilayer pipes than by producing them as solid versions of corresponding materials. This is achieved by the load being divided between a thin, corrosion-resistant inner layer (for example rust- and acid-resistant steel) and
15 a high-strength, pressure-resistant outer layer (for example fine-grained structural steel). This allows the overall consumption of steel to be reduced considerably and a large part of the remaining steel consumption to be shifted to low-cost materials.

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Abrasion-resistant pipelines of certain quality classes are only made possible in the first place by being made as multilayer pipes (for instance with a mechanical bond, see below), since materials (for example high-
25 strength steels with high levels of hardness) which in themselves cannot be made into pipes, or only with great difficulty, can be used as an inner layer.

30 A wide variety of other combinations of materials are possible, limited in principle only by the processing techniques that respectively come into consideration.

When constructing the pipe shell, a distinction is made between

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- full-area **metallurgical** bonding (this requires clad plate as a semifinished starting material), and

- purely **mechanical** bonding (for instance friction bonding) between inner pipe and outer pipe - preferably inner plate and outer plate and welding thereof at the edges of the plates.

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In the case of multilayer pipes with metallurgical bonding between the layers - for instance multilayer pipes of metal plates, preferably steel plates - a clad composite plate of two different (steel) materials is used as the semifinished starting material.

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The disadvantage of this process according to the prior art is on the one hand the high costs of the semifinished starting material, and consequently also of the end product, but on the other hand also an inadequate availability of this semifinished starting material on account of extremely limited production capacities for it in the world. Furthermore, the number of materials that can be processed in this way is limited. For instance, certain abrasion-resistant steels cannot be used as the inner layer if they cannot be welded, or only poorly, on account of their high carbon content.

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In the case of multilayer pipes with mechanical bonding, according to earlier prior art a number of finished pipes - preferably two - are used as the starting semifinished material. The process will be explained below on the basis of the example of two pipes (in the case of further layers, the statements made should be understood correspondingly):

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- Two finished pipes are produced to fit exactly from the materials to be combined and are pushed one into the other without friction, the outer pipe having to have a higher yield strength than the inner pipe.

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- By expanding (mechanically - for instance by means of an expanding head or by fluid pressure, in the latter case the pipes lying one inside the other being pressed into a die comprising the outer pipe), the inner pipe is pressed into the outer pipe with the outer pipe undergoing elastic expansion. Once the forces of expansion are removed, the outer pipe comes to lie with a force fit around the inner pipe because of the higher elastic recovery.

- Finally, the two materials are welded at the end faces.

The disadvantage of this prior-art process is caused by the outer pipe having to have a higher yield strength than the inner pipe, since otherwise the elastic recovery of the outer pipe that induces the force fit with the inner pipe and is therefore required is absent. This is disadvantageous in particular because high-strength materials - for instance particularly high-strength steels - as are particularly advantageous preferably for abrasion-resistant pipelines in the interior of the pipe, have high or even very high yield strengths, and are consequently not suitable for this production process.

In the meantime, however, WO 2006/066814 A1 has disclosed other processes which do not have these disadvantages and serve for the production of a multilayer pipe with mechanical bonding between the layers of material by means of a bending roll. In these,

- individual layers of material to be combined to form the multilayer pipe are laid one on top of the other, and

- the multilayer material formed in this way is formed into a multilayer pipe with the aid of a bending roll, a layer of material respectively acting as the inner pipe being pressed into a layer of material respectively acting as the outer pipe in the final phase of the pipe forming in the bending roll.

This process can be used to produce multilayer pipes which do not require semifinished material with roll-bonded and/or explosively applied cladding, but also are not subject to the restrictions that accompany the production of multilayered pipes according to the aforementioned prior art with frictional mechanical bonding of layers with respect to one another.

The use of semifinished material with roll-bonded and/or explosively applied cladding is avoided by first creating between the layers of material a first connection - for instance a weld seam - and then forcing the layer of material respectively acting as the inner pipe with a force fit into the layer of material respectively acting as the outer pipe during the pipe forming in the bending roll by a further connection between the layers of material - to be applied after deforming has progressed to a certain extent - and in this way holding it frictionally in the respective outer pipe, that is without having to expand the multilayer pipe and thereby encounter the disadvantages stated with respect to the aforementioned expansion process.

Nevertheless, this process has the technical disadvantage in terms of production that it requires a further connection between the layers of material to be created during the pipe forming in the bending roll, after deforming has progressed to a certain extent, which generally takes place by welding. For this connection it is therefore necessary to interrupt the

pipe forming in order to connect the two layers of material to one another at this further point. For this purpose, the still unfinished pipe must be removed from the bending roll and then the connection has to be
5 created, that is to say generally the weld seam has to be applied. As an alternative to this, welding may also take place in the bending roll, but this blocks the roll during this time. Then the pipe blank (also known as an open-seam pipe) can be re-introduced into
10 the bending roll in order to continue the production process there. Such a procedure is extremely time-intensive and therefore represents a considerable disadvantage in terms of production costs.

15 However, WO 2006/066814 A1 also teaches a process in which

- individual layers of material to be combined to form the multilayer pipe are laid one on top of
20 the other, a layer of material acting as the respective outer pipe forming a base plate, which has a stop edge, preferably a welded-on stop edge, approximately along both its longitudinal edges or approximately parallel thereto in each
25 case, and the overlying layer of material comes to lie loosely between these stop edges, and

- the multilayer material formed in this way is formed with the aid of the bending roll into a multilayer pipe, the layer of material
30 respectively acting as the inner pipe being clamped between the stop edges and the layer of material respectively acting as the inner pipe thereby being pressed with a force fit into the layer of material respectively acting as the
35 outer pipe in the final phase of the pipe forming in the bending roll.

According to this embodiment of WO 2006/066814 A1, consequently, even materials which cannot be welded, or only with great difficulty - such as for instance particularly high-strength steels - can be used as the
5 respective inner layer. Here, too, the layer of material acting as the inner pipe is pressed with a force fit into the layer of material respectively acting as the outer pipe already during the pipe forming in the bending roll, and so is held
10 frictionally in the respective outer pipe, that is without needing a connection such as for instance a weld seam that has to be created. Therefore, a time- and cost-intensive interruption of the pipe forming process in the bending roll is not required here
15 either. However, this production process once again has the disadvantage that here the inner layer of the pipe is not completely closed inwardly, since part of the inner circumference of the pipe is formed by the stop edges provided on the respective base plate, that
20 is to say the layer of material respectively lying on the outside, which has the result that the advantageous effects of the pipe inner layer, such as corrosion or abrasion resistance, cannot occur here. This disadvantage also cannot be overcome simply by build-up
25 welding in this region, since a welded connection between the material of the stop edge and that of the inner layer is indeed out of the question in the case of this process, which wishes to avoid welding between the inner layer and the outer layer.

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It is therefore an object of the present invention on the basis of the prior art according to WO 2006/066814 A1 to provide a process for producing a multilayer pipe which requires neither an interruption of the pipe
35 forming process for connecting the layers of material nor subsequent working in of parts of the layers of material.

This object is achieved according to the invention by a process for producing a multilayer pipe with the aid of a plate forming machine in which

- 5 - individual layers of material to be combined to form the multilayer pipe are laid one on top of the other, at least one of the layers of material consisting of more than one laid-on element,
- 10 - after that, a first connection, respectively, is then created between the bordering elements of the overlying layer of material and the adjacent layer of material,
- 15 - the multilayer material formed in this way is formed into the pipe and, during the deformation, the edges of the elements of the overlying layer of material that are still freely displaceable with respect to one another can move freely
- 20 toward one another in accordance with the extent to which deforming has progressed, on account of the different circumferential lengths of the inner pipe and the outer pipe,
- 25 - then, after deforming has progressed to a certain extent, these edges of the elements of the overlying layer of material that are moving toward one another butt against one another, and
- 30 - then the multilayer pipe is formed to completion with the aid of the plate forming machine, the edges of the elements of the overlying layer of material then no longer being able to move freely toward one another during this final forming, as
- 35 a result of which the layer of material respectively acting as the inner pipe is pressed with a force fit into the layer of material respectively acting as the outer pipe.

In the case of this process according to the present invention, the interruption of the pipe forming process in the plate forming machine - that is for instance in the bending roll - is avoided by at least two elements, which later form the inner layer, first, i.e. before the pipe forming process, being connected at the borders to the layer of material later forming the outer layer, that is to say generally being welded to said layer. During the pipe forming process, that is to say for example in the bending roll, the free ends of these elements then move toward one another, on account of the different bending radii (or circumferential lengths, which means the same) of the inner pipe and the outer pipe, and at some time butt against one another. Since, at this point in time, a curving of the plate to approximate a pipe has also already commenced, the edges of the abutting layers do not recoil from one another but remain abutting, exerting however - assuming a smoothly formed edge - on the inner layer of material a force which becomes greater as the deformation increasingly progresses and with which said inner layer is pressed against the outer layer. It should be noted that the process according to the invention is designed in such a way that it ensures that, from the instant at which the edges of the plates of the inner layer that are initially still freely displaceable with respect to one another butt against one another, the pipe to be formed has already been made to curve at every point at which the inner layer and the outer layer lie one on top of the other. This means that the pipe to be formed has a finite radius at every point at which the inner layer and the outer layer lie on top of one another (that is to say does not have an infinite radius anywhere there). This may be achieved - for instance with regard to the majority of the pipe body - preferably by adequate bending before the displaceable edges of the elements of the inner layer butt against one another, which may take place for instance by suitable

dimensioning and/or positioning of the elements of the inner layer. This may also be achieved (possibly also additionally) - preferably in the border region, that is to say the region that comes close to the longitudinal seam of the pipe that is later to be closed - by means of a preferably already performed initial bending of the layers of material intended for forming the pipe.

10 In this way, an interruption of the forming process - for instance for further welding of the layers of material - for forming a full-area inner layer of material from the material provided for this purpose in the interior of the pipe is no longer required.

15 Preferably, the process for producing a multilayer pipe according to the present invention is characterized in that the first connection between the layers of material is created by the latter being connected to one another approximately along one of the longitudinal and transverse edges of the overlying layer of material, or for instance along a line parallel thereto, but along the future longitudinal seam of the pipe. The elements laid on may consequently lie with their longitudinal edge parallel to the longitudinal edge of the underlying layer of material, but do not have to. For instance, it is also possible that they come to lie with their longitudinal edge transverse thereto. The connection to the underlying layer of material always takes place, however, along or parallel to the future longitudinal seam of the pipe.

35 It should be mentioned in this connection that whenever reference is made in this text to a connection along an edge or along a line (preferably only an imaginary line), this means any type of connection along the edge or line, irrespective of whether this connection exists along the entire edge or line or only along sections of the edge or line or else only at individual points (for

instance spot welds), for instance at two points - preferably at the end points of the edge or line - or even only at a single point at the edge or on the line.

5 In the finished multilayer pipe, the layer of material acting as the inner pipe may also form a pitch circle in cross section, which is achieved by the elements of the overlying layer of material, which later form the inner layer of the pipe, covering only part of the
10 surface area of the layer of material which later forms the outer layer, it having to be noted nevertheless that, in the course of the pipe forming process, they nevertheless butt against one another with their ends that are then still free, and so the inner layer is
15 pressed into the outer layer.

The layer of material acting as the inner pipe and forming a pitch circle in cross section of the finished multilayer pipe preferably thereby forms a channel at
20 the foot of the multilayer pipe.

After completion of the open-seam pipe, that is to say after completion of the main pipe forming process, for instance in the bending roll, a further connection,
25 preferably welding, may then take place between the layers of material and/or the edges of the elements of the overlying layer of material that butt against one another, in particular in order to seal this abutting edge here. However, this does not require an
30 interruption of the actual forming process. Rather, such a step only takes place after completion of the actual pipe forming process. This also does not require a further strip of material for the inner layer to be worked in. Rather, simple welding is sufficient
35 here. In cases in which complete sealing of the abutting edge is not important - for instance if only increased abrasion resistance of the inner layer is required - it is even possible to dispense with this sealing welding entirely.

With regard to the force with which the inner layer is to be pressed against the outer layer, reference should be made to the geometrical and physical conditions already known from WO 2006/066814 A1, which is hereby included in the disclosure content of the present invention by reference, and which uses

10 DA as the outside diameter of the outer pipe
 in mm,
 SA as the wall thickness of the outer pipe in
 mm,
 SI as the wall thickness of the inner pipe in
 mm,
15 σ_I as the yield strength of the inner pipe in
 N/mm²,
 Z_s as the upsetting allowance, indicated in
 parts per hundred, and
 E as the modulus of elasticity in N/mm².

20 The size of the elements of the overlying layer of
material (that is to say the later inner layer) and the
layer of the first connections between the elements of
the overlying layer of material and the adjacent layer
25 of material (that is to say the layer of material which
later generally forms the outer layer) should be chosen
in accordance with the conditions already stated in WO
2006/066814 A1, depending on the pressing force
desired.

30 The length of the neutral fiber of the outer pipe -
referred to here as L_{nfa} - is in this case:

$$L_{nfa} = (DA - SA) \cdot \pi$$

35 The length of the neutral axis of the inner pipe -
referred to here as L_{nfi} - is in this case:

$$L_{nfi} = (DA - 2 \cdot SA - SI) \cdot \pi$$

With a 100% degree of deformation of the pipe, the displacement of the free plate edges of the elements of the overlying layer of material (the later inner layer) - referred to here as L_{fv} - is then:

$$L_{fv} = L_{nfo} - L_{nfi}$$

10 The degree of upsetting of the inner pipe to achieve the yield strength - referred to here as ε_{st} - then becomes:

$$\varepsilon_{st} = \frac{\sigma_s}{E}$$

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and the corresponding upsetting length to achieve the yield strength becomes:

$$L_{st} = \varepsilon_{st} \cdot L_{nfi} \cdot (Z_s + 1)$$

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The extent to which deforming has progressed - referred to here as F_{for} - at which the free plate edges of the elements of the overlying layer of material are intended to butt against one another - so a maximum pressing force is wanted - is then (indicated as a value between 0 and 1) approximately:

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$$F_{for} = 1 - \frac{L_{st}}{L_{fv}}$$

30 and, given in parts per hundred:

$$F_{for} = \left(1 - \frac{L_{st}}{L_{fv}}\right) \cdot 100$$

If this expression is resolved with

- 5 DA as the outside diameter of the outer pipe
 in mm,
 SA as the wall thickness of the outer pipe in
 mm,
 SI as the wall thickness of the inner pipe in
10 mm,
 σ_I as the yield strength of the inner pipe in
 N/mm²,
 Z_s as the upsetting allowance indicated in
 parts per hundred and
15 E as the modulus of elasticity in N/mm²,

the extent to which deforming has progressed at which
the free plate edges of the elements of the overlying
layer of material (that is to say the later inner
20 layer) are intended to butt against one another, so a
maximum pressing force is wanted, is then obtained by
the following expression:

$$F_{for} = \left(1 - \frac{\frac{\sigma_I}{E} \cdot (DA - 2 \cdot SA - SI) \cdot \pi \cdot (Z_s + 1)}{(DA - SA) \cdot \pi - (DA - 2 \cdot SA - SI) \cdot \pi}\right) \cdot 100$$

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The upsetting allowance in this case takes into account
the production inaccuracy in the fixing of the at least
one further material layer connection and compensates
for this by achieving at least the desired pressing
30 force of the inner pipe against the outer pipe.

In practice, therefore, whenever for instance it is
wished to form a complete inner pipe from the layer of
material lying on the inside, while at the same time

wanting the maximum pressing force achievable by means of the process according to the invention - with two overlying elements that later form the layer - the overlying elements are first welded along the longitudinal edges of the layer of material later forming the outer layer and these elements (forming the later inner layer) are chosen in respect of their size and their geometry in such a way that a gap remains between their free edges, a gap which closes in the course of the pipe forming process, and then the two edges, then butting against one another, are only made to butt against one another by the further pipe forming process still to be performed to the extent allowed by the yield strength of the material of the future inner layer.

Preferably, in the case of the process for producing a multilayer pipe with the aid of the process according to the present invention, the multilayer pipe is closed by a welding of the outer pipe along the pipe seam and a build-up welding of the inner pipe, in order in this way to complete the multilayer pipe body.

The layers of material may also be connected at the end faces of the pipe, for instance in order to prevent the ingress of moisture there between the layers of material that are indeed not metallurgically bonded over the full surface area.

A preferred application of the process according to the present invention is that of producing double-layer pipes according to the invention, although the invention is not restricted to double-layer pipes and it is possible in principle for pipes according to the invention of three, four or even more layers to be produced by this process.

In a further particularly preferred embodiment of the present invention, plates, preferably metal plates and

particularly preferably steel plates, are used as the layer of material or elements of the layer of material.

5 In the process for producing a multilayer pipe according to the present invention, at least one of the connections of the layers of material is also preferably performed as welding, which is suitable in particular for the aforementioned metal plates, preferably steel plates.

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Suitable as the plate forming machine is, for instance, a bending roll, that is to say for example a three-roll rounding machine, but also a press/die arrangement, as used for instance as part of the UOE (U forming, O forming, Expanding) pipe forming process known from the prior art (with respect to the UOE process, see for example: Hiersig, Heinz M., Lexikon Maschinenbau, Heidelberg 1997, page 704 et seq. under the heading "Längsnaht-Großrohrherstellung" [longitudinal-seam large pipe production]) or else the so-called JCO pipe forming process. However, it should be taken into consideration that, with the process according to the present invention, it may be necessary - depending on the combination of materials - to dispense with the final step of expanding, if this would excessively worsen the pressing of the layers of material against one another on account of the relative yield strengths of the materials of the respective inner layer in relation to the outer layer.

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In the case of the JCO process, the pipe is formed by the plate first being brought into the form of a recumbent 'J' and then a recumbent 'C' by means of a blade in a press. After that, it is then bent into the 'O' form - as also in the case of the UOE process.

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The fact that the actual pipe forming process in the case of the process according to the present invention no longer has to be interrupted for the creation of a

further connection between the layers of material means that the process according to the invention can now be operated as a continuous production process in which the layers of material to be combined or elements thereof are respectively unwound from a wound-up strip and then continuously laid one on top of the other and continuously connected, preferably welded, the subsequent pipe forming process likewise taking place continuously, in that a forming line which forms an open-seam pipe from the layers of material laid continuously one on top of the other serves as the plate forming machine. Such forming lines for pipe forming are known for instance from the prior art, as described in US 3 327 383 and hereby included in the disclosure content of this document.

Exemplary embodiments, which should not be understood in a restrictive sense, are discussed below with reference to the drawing, in which:

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Figure 1 shows a perspectively outlined plan view of two layers of material laid one on top of the other and intended to be combined to form the multilayer pipe,

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Figure 2 shows a perspectively outlined view looking into a - not yet completed - multilayer pipe from one end face during the production process according to the invention, to be specific in the process step where the multilayer material formed thereby is formed into the pipe with the aid of the plate forming machine, but the edges of the two overlying elements are still freely movable with respect to one another,

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Figure 3 shows a perspectively outlined view looking into a - likewise not yet completed - multilayer pipe from one end face during the

production process according to the invention, to be precise in the process step where, after deforming has progressed to a certain extent, the two free abutting edges of the overlying elements now butt against one another,

Figure 4 shows a perspective cross section through a completed multilayer pipe with an inner layer and an outer layer,

Figure 5 shows a perspective cross section through a multilayer pipe with an inner layer and an outer layer in a view of a detail in the region of the weld seam, and

Figure 6 shows a continuous pipe forming process according to the present invention in a basic representation in which the layers of material to be combined or the elements thereof are respectively in the form of a wound-up strip (also known as a coil), from which they are unwound and then continuously laid one on top of the other,

Figure 7 shows the starting situation of the process according to the invention when the plate forming is performed by means of a UO(E) press/die arrangement,

Figure 8 shows the forming step that forms a 'U', to be precise by means of a press (not represented here), which drives a correspondingly shaped head downward, where the layers of material are thereby driven altogether into a die (which likewise cannot be seen here), and

Figure 9 shows the forming step that forms an 'O', that is to say shapes an open-seam pipe, to be precise by means of a press (not represented here), which drives two half-round-shaped heads from below and above against the pipe body to be formed, where the layers of material are once again thereby formed altogether into a round shape - seen in cross section.

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Figure 1 shows a perspectively outlined plan view of two layers of material 1a, 1b, 2 laid one on top of the other and intended to be combined to form the multilayer pipe, one of the layers of material, to be specific the laid-on layer of material 1a, 1b, which is later to form the inner layer of the multilayer pipe, consisting of two elements 1a, 1b - preferably plates - laid on in the longitudinal direction of the pipe, which at the beginning of the process according to the invention are connected for the first time - preferably by a weld seam - along their longitudinal edges 3a, 3b to the adjacent layer of material 2, which is later to form the outer layer of the pipe.

25 Figure 2 shows a perspectively outlined view looking into a - not yet completed - multilayer pipe 5 from one end face during the production process according to the invention, to be specific in the process step where the multilayer material formed thereby is formed into the pipe 5 with the aid of the plate forming machine, for instance a bending roll (the plate forming machine itself, that is for instance the bending roll, has been blanked out here and therefore cannot be seen), the edges 4a, 4b of the elements 1a, 1b that are not yet
30 connected to the adjacent layer of material 2 being freely displaced with respect to one another during the deformation in accordance with the extent to which deforming has progressed, on account of the different bending radii of the inner pipe 1, 1a, 1b and the outer

pipe 2. The first connection between the two layers of material 1, 1a, 1b, 2 already took place here at the edges 3a, 3b, which run along the forming longitudinal edge of the inner pipe 1, 1a, 1b and were already
5 created before the pipe forming process - for instance by welding. In the region of this first connection 3a and 3b of the layers of material 1, 1a, 1b, 2, however, the latter cannot be displaced with respect to one another on account of their connection to one another,
10 but remain fixed with respect to one another here. It should also be noted that, even in the upper region of the representation (that is to say in the region that runs toward the still open seam in the pipe) and where the inner layer and outer layer 1, 1a, 1b, 2 in
15 particular also lie one on top of the other, the pipe is already rounded (the radius is therefore not infinite anywhere here). This fact can possibly not be seen quite so well in the perspective representation of Figure 2, so this clarifying explanation has been given
20 here.

Figure 3 shows a perspectively outlined view looking into a - likewise not yet completed - multilayer pipe 5 from one end face during the production process
25 according to the invention, to be precise in the process step where, after deforming has progressed to a certain extent, the two free abutting edges 4a, 4b of the overlying elements 1a, 1b now butt against one another. Following this, the multilayer pipe 5 can
30 then be formed to completion with the aid of the plate forming machine (which can no longer be seen), the layers of material then not being displaced with respect to one another any longer during this final forming on account of the butting against one another
35 of the edges 4a and 4b, as a result of which the layer of material 1, 1a, 1b respectively acting as the inner pipe is pressed with a force fit into the layer of material 2 respectively acting as the outer pipe. Here, too, it should likewise be noted, as already with

respect to Figure 2, that, even in the upper region of the representation (that is to say in the region that runs toward the still open seam in the pipe) and where the inner layer and outer layer **1, 1a, 1b, 2** in particular also lie one on top of the other, the pipe is already rounded (the radius is therefore not infinite anywhere here). This fact can possibly not be seen quite so well in the perspective representation of Figure 3, so this clarifying explanation has been given here.

Figure 4 then shows a perspective cross section through a completed multilayer pipe **5** with an inner layer (also referred to as the inner pipe, inner pipeline, inner plate, etc.) **1, 1a, 1b** and an outer layer (also referred to as the outer pipe, outer pipeline, base plate, etc.) **2**, the multilayer pipe **5** having been closed by a welding **7** of the outer pipe **2** along a pipe seam **8** and a build-up welding **9** of the inner pipe **1, 1a, 1b**. The first connections **3a, 3b** between the layers **1, 1a, 1b, 2**, which already took place before the actual pipe forming process, are likewise indicated; similarly, the abutting edge of the two initially still free edges **4a, 4b** of the two inner layer elements **1a, 1b** can be seen.

Figure 5 shows a perspective cross section through a multilayer pipe as shown in Figure 4 with an inner layer **1a, 1b** and an outer layer **2** in a view of a detail in the region of the two weld seams **3a, 3b, 7, 9**.

Figure 6 shows a continuous pipe forming process according to the present invention in which the layers of material **1a, 1b, 2** to be combined or elements thereof are respectively in the form of a wound-up strip (also known as a coil), from which they are unwound and then continuously laid one on top of the other. This is then followed by a likewise continuous welding of the layers at the outer border by means of a

respective welding unit 10, for instance a laser or a roll seam welding machine or a spot welding machine or the like. Arc welding is also conceivable here. The pipe forming process which then follows takes place
5 once again continuously, to be precise by means of a forming line which forms an open-seam pipe 5 by means of contoured rolls 6 from the layers of material 1a, 1b, 2 that are lying continuously one on top of the other and are welded at the border, and so serves as a
10 plate forming machine. Such forming lines for pipe forming are known for instance from the prior art, as described in US 3 327 383. (Note: in the perspective side view of the forming line that can be seen here, the contoured rolls are represented as cylinders for
15 reasons of simplifying the representation. By contrast, in the lower part of the representation, which shows stations of the forming line in their respective cross section, the contoured rolls 6 can be correctly seen.)

20 This representation is intended however to illustrate the process once again, in that the unit serving for this purpose is depicted from the side in its upper part and is depicted in cross section, to be precise
25 counter to the feeding direction 12, in the lower part of the representation, at various stations identified by assignment arrows 11.

Consequently, here, two material layer elements 1a, 1b
30 and one layer of material 2 run together from above. The material layer elements 1a, 1b supplied continuously from above as a strip have in this case a width which is suitable for forming the desired inner wall of the pipe to be produced after the production
35 process according to the invention is carried out and, moreover, also for being adequately upset by the pressing force produced as a result of the pipe forming. The details of the dimensioning and positioning of the elements of the material layer that

is intended to come to lie on the inside have already been discussed above in the general part of the description here, to which reference is made at this point. The layer of material 2 supplied from below
5 serves later as the outer layer and therefore has as its width the outer circumference of the pipe 5 to be produced.

When the two layers 1a, 1b, 2 are lying one on top of
10 the other, they are welded respectively at their borders by means of a welding unit 10, so that the elements 1a, 1b of the later inner layer are then respectively connected to the later outer layer 2 at the outer border. By contrast, in the middle of the
15 layer of material 2 forming the later outer wall, the two elements 1a, 1b of the later inner pipe layer still lie with their edges there unattached.

In the following forming line, which then continuously
20 forms a pipe 5 from the multilayered plate 1a, 1b, 2 by means of an arrangement of contoured rolls 6 (see the note above with respect to the representation of the contoured rolls), the aforementioned still unattached edges of the inner-lying material layer elements 1a, 1b
25 are then pushed toward one another as a result of the different bending radii of the outer pipe and inner pipe, and then, as a result of the butting of the latter against one another, close plate edges that were still freely displaceable at this point to form an
30 inner layer 1. After that, the deforming process to form the pipe proceeds in such a way that the two inner layer elements 1a, 1b are then pushed further against one another, which then however leads to upsetting of the inner layer 1 and, as a result of this, to pressing
35 thereof against the further forming outer layer 2, until finally an open-seam pipe 5 is obtained, and this can be closed along the open seam by welding. If need be, the abutting edges of the two inner layer elements 1a, 1b may also be welded to one another and/or to the

outer layer of material 2 in advance - for instance by means of a laser through the still open seam.

Figure 7 shows the starting situation of the process according to the invention when the plate forming is performed by means of a UO(E) press/die arrangement. The layer of material 2 later lying on the outside lies underneath here and the two elements 1a, 1b forming the later inner layer 1 lie on the outside. They have already been welded to the lower layer 2 at the borders and been rounded there together with the lower layer 2. If appropriate, the bordering welding of the layers 1a, 1b, 2 may, however, also take place after the rounding of the border region. In the middle, the two overlying elements 1a, 1b are still spaced apart from one another.

Figure 8 then shows the forming step that forms a 'U', to be precise by means of a press (not represented here), which drives a correspondingly shaped head 13 downward, where the layers of material 1a, 1b, 2 are thereby driven altogether into a die (which likewise cannot be seen here). The inner-lying material layer elements 1a, 1b are thereby moved toward one another with their still freely movable plate edges - as a result of the different radii of the outer layer 2 and inner layer 1, 1a, 1b.

Figure 9 then shows the forming step that forms an 'O', that is to say shapes an open-seam pipe, to be precise by means of a press (not represented here), which drives two half-round-shaped heads 14, 15 from below and above against the pipe body to be formed, where the layers of material 1a, 1b, 2 are once again thereby formed altogether into a round shape - seen in cross section. Once again, the inner-lying material layer elements 1a, 1b are thereby moved toward one another with their still freely movable plate edges as a result of the different radii of the outer layer and inner

layer, to be precise until they butt against one another and in this way cause the formation of a continuous inner layer 1, which is then pressed into the outer layer 2 during further pipe forming, since
5 the originally free edges of the inner layer elements 1a, 1b cannot then be moved toward one another any longer. As a result of the curving, they do not recoil from one another, but come to lie against the outer wall 2.

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It should be noted that the process according to the invention can be carried out in a similar way by means of a press/die arrangement designed for the so-called 'JCO' process. A procedure corresponding to the JCO
15 process is then followed here, but modified in such a way that once again two layers of material are formed, as in the case of the UO(E) process modified according to the invention. Here, too, the overlying elements 1a, 1b are welded at the borders to the layer of
20 material 2 forming the later outer layer and then an open-seam pipe is formed on the basis of the JCO process. Once again, the desired effect according to the invention thereby occurs, with the initially free plate edges of the inner layer elements 1a, 1b butting
25 against one another, thereby forming a continuous inner layer 1 and then being pressed against the outer layer 2 as a result of the different bending radii of the outer layer and inner layer.

30 In all cases, that is to say both in the case of the UO(E) process modified according to the invention and in the case of the JCO process modified according to the invention, after they butt against one another, the initially still freely movable abutting edges of the
35 two inner layer elements 1a, 1b can be welded to one another and/or to the outer layer 2, which may take place for instance through the still open seam of the open-seam pipe, preferably by means of a laser welding device.

Title: Production-optimized process for producing a multilayer pipe

Patent claims

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1. A process for producing a multilayer pipe (5) with the aid of a plate forming machine, characterized in that

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- individual layers of material (1, 2) to be combined to form the multilayer pipe (5) are laid one on top of the other, at least one of the layers of material (1) consisting of more than one laid-on element (1a, 1b),

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- after that, a first connection (3a, 3b), respectively, is then created between the bordering elements of the overlying layer of material (1a, 1b) and the adjacent layer of material (2),

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- the multilayer material formed in this way is formed into the pipe (5) and, during the deformation, the edges (4a, 4b) of the elements (1a, 1b) of the overlying layer of material (1a, 1b) that are still freely displaceable with respect to one another can move freely toward one another in accordance with the extent to which deforming has progressed, on account of the different circumferential lengths of the inner pipe (1a, 1b) and the outer pipe (2),

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- then, after deforming has progressed to a certain extent, these edges (4a, 4b) of the elements (1a, 1b) of the overlying layer of material (1a, 1b) that are moving toward one another butt against one another, and

- then the multilayer pipe (5) is formed to completion with the aid of the plate forming machine, the edges (4a, 4b) of the elements (1a, 1b) of the overlying layer of material (1a, 1b) then no longer being able to move freely toward one another during this final forming, as a result of which the layer of material (1a, 1b) respectively acting as the inner pipe is pressed with a force fit into the layer of material (2) respectively acting as the outer pipe.

2. The process for producing a multilayer pipe (5) as claimed in claim 1, characterized in that the forming of the multilayer material into the pipe is designed in such a way that, when deforming has progressed to the extent that the edges (4a, 4b) of the elements (1a, 1b) of the overlying layer of material (1a, 1b) that were previously moving toward one another butt against one another, the pipe to be formed has already been made to curve at every point at which the inner layer and the outer layer lie one on top of the other.

3. The process for producing a multilayer pipe (5) as claimed in claim 1 or 2, characterized in that the first connection between the layers of material (1, 1a, 1b, 2) is created by the latter being connected to one another approximately along one of the longitudinal and transverse edges of the overlying layer of material (1, 1a, 1b), or for instance along a line parallel thereto, but along or parallel to the future longitudinal seam (8) of the pipe.

4. The process for producing a multilayer pipe (5) as claimed in claim 1, 2 or 3, characterized in that, in the finished multilayer pipe (5), the layer of

material (1, 1a, 1b) acting as the inner pipe forms a pitch circle in cross section.

5. The process for producing a multilayer pipe (5) as
5 claimed in one of claims 1 to 4, characterized in
that the layer of material (1, 1a, 1b) acting as
the inner pipe and forming a pitch circle in cross
section of the finished multilayer pipe (5) forms a
channel at the foot of the multilayer pipe.
- 10 6. The process for producing a multilayer pipe (5) as
claimed in one of claims 1 to 5, characterized in
that a connection, preferably welding, takes place
between the edges (4a, 4b) of the elements of the
15 overlying layer of material (1a, 1b) that butt
against one another.
7. The process for producing a multilayer pipe (5) as
claimed in one of claims 1 to 6, characterized in
20 that the multilayer pipe (5) is closed by a welding
(7) of the outer pipe (2) along the pipe seam (8)
and a build-up welding (9) of the inner pipe (1,
1a, 1b).
- 25 8. The process for producing a multilayer pipe (5) as
claimed in one of claims 1 to 7, characterized in
that the layers of material (1, 1a, 1b, 2) are
connected at the end faces of the pipe (5).
- 30 9. The process for producing a multilayer pipe (5) as
claimed in one of claims 1 to 8, characterized in
that a double-layer pipe is produced as the
multilayer pipe (5).
- 35 10. The process for producing a multilayer pipe (5) as
claimed in one of claims 1 to 9, characterized in
that plates, preferably metal plates and
particularly preferably steel plates, are used as

the layer of material (1, 2) or elements (1a, 1b) of the layer of material (1).

- 5 11. The process for producing a multilayer pipe (5) as claimed in one of claims 1 to 10, characterized in that at least one of the connections (3a, 3b, 4a, 4b) of the layers of material (1, 2) is performed as welding.
- 10 12. The process for producing a multilayer pipe (5) as claimed in one of claims 1 to 11, characterized in that the process is designed as a continuous process in which the layers of material (1, 1a, 1b, 2) to be combined or elements (1a, 1b) thereof are
15 respectively unwound from a wound-up strip and then continuously laid one on top of the other and continuously connected, preferably welded, the subsequent pipe forming process likewise taking place continuously, in that a forming line which
20 forms an open-seam pipe (5) from the layers of material laid continuously one on top of the other serves as the plate forming machine.
- 25 13. The process for producing a multilayer pipe (5) as claimed in one of claims 1 to 11, characterized in that a bending roll is used as the plate forming machine.
- 30 14. The process for producing a multilayer pipe (5) as claimed in one of claims 1 to 11, characterized in that a UO(E) press/die arrangement (13, 14, 15) is used as the plate forming machine.
- 35 15. The process for producing a multilayer pipe (5) as claimed in one of claims 1 to 11, characterized in that a JCO press/die arrangement is used as the plate forming machine.