

Title: Method for the high-speed production of a multi-layered tube

The present invention relates to a method for the high-speed production of a multi-layer tube. Multi-layer tubes are preferably used in cases of high requirements on corrosion-resistance or abrasion-resistance.

Corrosion-resistant pressure vessels or pressure lines can be produced by using multi-layer tubes in a more cost-efficient way than by using solid products from the respective materials. This is achieved by load-sharing between a thin corrosion-resistant inner layer (e.g. corrosion-resistant and acid-resistant steel) and a high-strength, pressure-resistant external layer (e.g. fine-grained structural steel). In such way the overall steel consumption can be reduced significantly and a big portion of the remaining steel consumption can be shifted to cost-efficient materials.

Abrasion-resistant lines of certain quality grades can be provided only as multi-layer tubes (for instance with mechanical bonding, see below), since such materials (i.e. high strength steels of high hardness levels) can be implemented as inner layers, which singly can hardly or impossibly be processed into tubes.

Other material combinations are possible in large variety, in principle, the possibility of combining materials is limited only by the respective possible processing techniques.

Regarding the structure of the tube coating, a distinction is made between:

- full-surface **metallurgical** bonding (this requires plated sheet material as a starting semi-finished product), and
- purely **mechanical** bonding (e.g. as a friction bonding) between the inner and the outer tube, preferably between the inner and the outer sheet, with welding at the sheet edges.

In multi-layer tubes with metallurgical bonding between the layers - for example multi-layer tubes out of metal sheets, preferably out of steel sheets – a plated composite sheet of two different (steel) materials is used as starting semi-finished product.

5 The disadvantage of this method according to the state of the art is the high cost of the starting semi-finished material and hence of the finished products on the one hand and the insufficient availability of the starting semi-finished material because of very limited global production capacities for it on the other hand. Furthermore, the number of materials which can be processed in such way is limited. Some abrasion-resistant steels for instance cannot be used as inner layers if they cannot or can
10 only with difficulty be welded because of their high carbon content.

In case of multi-layer tubes with mechanical bonding according to some prior art a number of - preferably two – finished tubes are used as starting semi-finished products. This method shall be explained on the basis of an example with two tubes as follows (in the case of more layers the explanation has to be interpreted accordingly):
15 ly):

- Two finished tubes of materials to be combined are manufactured in a precisely fitting manner and put one into another without friction, wherein the outer tube must have a higher yield strength than the inner one.
- 20 - By expanding (mechanically – for example by an expansion stamp or by fluid pressure, whereby in the latter case the tubes situated into each other are pressed into a die comprising the outer tube) the inner tube - under elastic widening also of the outer tube - is pressed into the outer tube. After removal of the expansion forces, the outer tube
25 because of its higher elastic spring-back lies force-fitted around the inner tube.
- Finally, the two materials are welded at the end faces.

The disadvantage of this method according to the prior art is due to the fact that the outer tube is required to have a higher elastic yield strength than the inner one,

since the spring-back causing the force-fitting, which is hence necessary, would otherwise not be available. This is in particular disadvantageous, because high-strength materials e.g. especially high-strength steels - as such are especially advantageous in abrasion-resistant pipelines on the inside of the tube - have high or very high yield strengths, and thus are not suitable for this manufacturing method.

Meanwhile other methods are also known from WO 2006/066814 A1, which don't have these disadvantages and which serve for manufacturing of a multi-layer tube with mechanical bonding between material layers by means of a bending roller, wherein

- single material layers to be combined into the multi-layer tube are put on top of each other, and
- thus built multi-layer material is shaped by means of the bending roller to a multi-layer tube, wherein in the final stage of the tube forming in the bending roller the material layer which serves as inner tube is pressed into a force-fitted manner into a material layer which serves as outer tube, respectively.

By means of this method, multi-layer tubes can be produced without using rolled clad and/or explosive-cladded semi-finished products, which on the other hand are not subject to the limitations resulting from the production of multi-layer tubes according to the above-mentioned state of the art with frictional mechanical bonding of layers with each other.

Use of rolled clad and/or explosive-cladded semi-finished products is avoided by first creating a first connection between the material layers – for example a welding seam – and afterwards the respective material layer which serves as inner tube is pressed into the respective material layer which serves as outer tube during the tube shaping process in the bending roller in a force-fitted manner, by means of a further connection between the material layers to be provided after a specific shaping progress, and it is fixed in this way in the respective outer tube in a frictionally engaged manner, and this without the necessity to widen up the multi-layer tube,

and hence without incurring the disadvantages of the expansion method as mentioned above.

However, this method has the disadvantage with respect to production technology that it is hereby necessary to create a further connection between the material layers, during the tube shaping in the bending roller after a specific shaping progress, which is normally done by welding. For this connection it is hence necessary to interrupt the tube shaping in order to connect the two material layers with each other at this additional location. For that reason the still unfinished tube has to be taken out of the bending roller and then the connection, which is normally a welding seam, must be created. Alternatively hereto, the welding can be done in the bending roller, which however is then blocked during this procedure. Thereafter, the semi-finished tube (also referred to as open seam tube) can be put again in the bending roller, in order to continue the manufacturing process there. Such a procedure is extremely time-consuming and therefore presents a significant disadvantage in terms of production costs.

WO 2006/066814 A1, however, teaches another method as well, according to which

- single material layers which are to be combined into a multi-layer tube are put on top of each other, wherein a respective material layer which serves as an outer tube provides a basic sheet, which comprises approximately along its both long edges or approximately parallel thereto one, preferably welded, stopper edge and the overlying material layer will be placed loosely between these stopper edges, and
- the multi-layer material created in such way is shaped by means of the bending roller to a multi-layer tube, wherein the respective material layer which serves as inner tube is clamped between the stopper edges, and in the final phase of the tube shaping in the bending roller, the respective material layer which serves as inner tube is thus pressed in a force-fitted manner into the respective material layer which serves as an outer tube.

Thus, according to this embodiment of the WO 2006/066814 A1, also such materials – as for example special high-strength steels - which cannot or can only hardly be welded can be used as respective inner layer. Also here, the material layer which serves as inner tube is pressed during the tube forming in the bending roller in a force-fitted manner into the respective material layer which serves as outer tube and thus is held in a friction-bonded manner in the respective outer tube, and this without the necessity to create a connection, for example by a welding seam. Hence a time- and cost-intensive interruption of the process of the tube shaping in the bending roller is not necessary. However, this manufacturing method has again the disadvantage, that here the inner layer of the tube is not completely closed inwardly, since one part of the tube inner circumference is formed by the stopper edges placed on the respective basic sheet, that is to say the respective outer material layer, leading to the result that the advantageous effects of inner layer of the tube - like corrosion-resistance and abrasion-resistance - cannot occur. This disadvantage also cannot be simply resolved by a deposition welding in this region since a weld connection between the material of the stopper edge and the one of the inner layer is not feasible in this method, which is just directed at avoiding a welding between the outer and inner layers, .

Meanwhile however, an optimized process of the WO 2010/145680 A1 is also known, in which neither interruption of the tube manufacturing for connecting the material layers nor a subsequent incorporation of parts of material layers is necessary. Herein

- separate material layers which are to be combined into the multi-layer tube are put on top of each other, wherein at least one of the material layers consists of more than one overlaid elements,
- hereafter, a respective first connection between the rim-sided elements of the overlying material layer and the adjacent material layer is created,
- the multi-layer material created in such way is shaped to a tube and during the shaping, the edges of the elements of the overlying material layer, which are still freely movable against each other, will move freely towards

each other because of the different circumference lengths of the inner tube and of the outer tube, after a specific shaping progress,

- thereafter these edges of the elements of the overlying material layer which are moving towards each other abut against each other after a specific shaping progress, and
- then the multi-layer tube is finally shaped by means of a sheet forming machine, wherein during this final shaping, the edges of the elements of the overlying material layer now cannot further move towards each other freely, and thus the respective material layer which serves as an inner tube is pressed into a force-fitted manner into the material layer which serves as an outer tube, respectively.

In this method of the state of the art, the interruption of the process of the tube shaping in the sheet metal forming machine – for example in the bending roller – is avoided by a rim-sided connection of at least two elements which provide later the inner layer to the material layer which provides later the outer layer, made at first, i.e. before the tube shaping process, normally by welding. During the tube shaping process, so for example in the bending roller, the free ends of these elements move freely due to different bending radii (or circumferences, meaning actually the same) of the inner and outer tubes towards each other and eventually meet each other. Since at this point of time, the bending of the sheet to a tube is already in progress, the edges do not spring off from each other but rather remain in contact to each other, wherein they however – provided an edge being smoothly shaped - apply a force on the inner material layer, which is increasing with the advancing of the shaping and by which it is pressed against the outer layer. Thus, an interruption of the shaping process – e.g. for further welding of the material layers – for the shaping of a full-surface material inner layer of dedicated material is not necessary any more.

However, this procedure has the disadvantage, that here a subsequent processing step, namely that for welding of the abutting edge inside of the tube is necessary. Besides, according to this process such an additional third weld seam is created -

namely at the abutting edge – inside the tube, which presents an additional failure source.

Hence, the object of the present invention - in view of WO 2010/145680 A1 - is to provide a process for the production of multi-layer tubes in which an additional weld-
 5 ing seam on the inside of the tube is avoided, and at the same time the advantages of the process according to WO 2010/145680 A1 with respect to production technology are maintained, so neither an interruption of the tube forming process for connection of material layers nor a subsequent incorporation of parts of material layers is required.

10 This process is achieved according to the present invention by a method for the high-speed production of a multi-layer tube by means of a sheet metal forming machine, wherein the multi-layer tube comprises at least one first material layer and a material layer adjacent to said first material layer, wherein

- 15 - the adjacent material layer is at least slightly bent, (whereby “bent” is to be understood as an elastic as well as a plastic deformation,)
- the material layers to be combined into the multi-layer tube are put on top of each other, wherein the first material layer is positioned as overlying material layer on the adjacent material layer,
- 20 - a first connection between the overlying material layer – which serves as inner tube after the tube shaping – and the adjacent material layer – which serves as outer tube after the tube shaping - is created by
 connecting the overlying material layer with the adjacent material layer – preferably approximately - along a first edge of the overlying material layer or - preferably approximately - along a line parallel thereto,
- 25 - a second connection between the overlying material layer and the adjacent material layer is created by

connecting the overlying material layer with the adjacent material layer - preferably approximately – along a second edge of the overlying material layer or – preferably approximately - along a line parallel thereto, and

- the thus formed multi-layer material is shaped by means of the sheet metal forming machine into the multi-layer tube, wherein

during this shaping process, after a certain degree of shaping, the respective overlying material layer which serves then as inner tube is compressed between the two material layer connections in (partly) circumferential direction and is thus pressed into the respective adjacent material layer, which serves then as outer tube.

It is to be emphasized that the above-mentioned process steps in the order of their listing in the aforesaid text require by no means the same order in the execution of the process according to the invention. During execution of the method, - apart from technical necessities in the order, such as the last mentioned step of the tube shaping by means of sheet metal forming machine, which effectively requires the previous formation (production) of the multi-material - the order rather does not necessarily matter. So, for example the two material layer connections can be provided (preferably roughly) at the same time instead of sequentially. It is for instance also possible to provide one of the connections between the material layers first and only after that to provide the bending, in order to provide thereafter the second connection between the material layers. The bending of the adjacent material layer – preferably lying below and providing the outer layer after the shaping of the (multi-layer) tube - thereby brings its edges - as seen in the tube cross-section - closer to each other. In the method according to the present invention the interruption of the tube shaping process in the sheet metal forming machine and also an additional welding seam inside the tube is avoided, since here first of all, neither an interruption of the shaping process in the sheet metal forming machine for connecting the material layers nor for forming a full-surface material inner layer of a dedicated material on the inside of the tube nor a further (third) welding seam is required, since the inner material layer, on the one hand, can be formed as a single piece and, on the other hand, a bending of the adjacent material layer, as for instance “preloading” of the

material, is performed, which enables the connection of the two material layers with each other already before the (further) tube shaping process in the sheet metal forming machine. The connection of the material layers can be performed prior to the actual tube shaping process in the sheet metal forming machine (tube forming machine) and hence does not disturb this process later any more.

Any possible bending of the adjacent material layer along (for instance one or both) its edges is performed according to the present invention preferably already to the final radius of the multi-layer tube which is to be produced, since this avoids a subsequent processing, which is often connected with manufacturing problems such as edge-crushing. Such a bending to the final radius can be carried out for example preferably by means of a bending press for sheet metal plates, as it is known from WO 2010/118759 A2.

In a preferred embodiment of the method for the high-speed production of a multi-layer tube by means of a sheet metal forming machine according to the present invention

single material layers which are to be combined into a multi-layer tube are put on top of each other and

then a first connection between the overlying material layer and the adjacent material layer is provided by connecting the overlying material layer with the adjacent material layer approximately along the first edge of the overlying material layer or approximately along a line parallel thereto,

whereupon the thus formed multi-layer material – and therefore also the adjacent material layer – is at least slightly bent (as to the term bending as plastic or elastic deformation, please see above, there explained with regard to adjacent material layers) in the region, in which the material layers are connected with each other approximately along the edge or along a line parallel thereto by means of the first connection,

the second still free edge of the overlying material layer is positioned relative to the adjacent material layer in the direction of an also still free edge of the adjacent material layer, and

after that the second connection between the overlying material layer and the adjacent material layer is created by

connecting the overlying material layer with the adjacent material layer approximately along the second still free edge of the overlying material layer or approximately along a line parallel thereto, and

the thus formed multi-layer material is shaped into a multi-layer tube by means of the sheet metal forming machine, wherein

during this shaping process, after a certain degree of shaping, the respective overlying material layer which then serves as inner tube is compressed in (partly) circumferential direction and is thus pressed into the respective adjacent material layer which then serves as outer tube.

In the above-described embodiment of the process according to the present invention, therefore again first of all the interruption of the tube shaping process in the sheet metal forming machine and also an additional welding seam inside the tube is avoided, since once again neither an interruption of the shaping process for connecting the material layers nor for forming a full-surface inner material layer of the dedicated material inside the tube and also no (third) welding seam is required, since this is omitted by "preloading" of the multi-layer material through means of the initially one-sided connection of the layers, by the elastic or plastic bending in this region, by the "moving", preferably "dragging-over" towards the other end and finally by the fixing of this preload at this other end through means of connecting again.

This above-described embodiment of the manufacturing according to the invention is advantageous, because here no initial (starting) - plastic or elastic - deformation of the adjacent material layer is required. This bending is rather achieved only in the course of carrying out the manufacturing process according to the invention, namely by positioning, preferably dragging-over of the overlying material layer simultane-

ously with this step of the process. Preferably, the circumference (width) - as seen in the cross-section of the tube - of the respective material layer B_i which is serving as an inner tube between both connections of material layers with each other is selected in such a way that the following applies

$$B_i > L_{nfa} - \pi(SA + SI) - (d_1 + d_2),$$

with B_i being the (partial) circumference (width before the tube shaping) of the respective material layer which serves as inner tube, as seen in the cross-section of the tube, between the two connections between the material layers, for instance measured in mm,

L_{nfa} being the circumference (width before the tube shaping) of the respective material layer which serves as outer tube, as seen in the cross-section of the tube, for instance measured in mm,

SA being the wall thickness of the respective material layer which serves as outer tube, for instance measured in mm,

SI being the wall thickness of the respective material layer which serves as inner tube, for instance measured in mm, and

d_1 being the distance of the first connection along the first edge of the overlying material layer or along a line parallel thereto from the corresponding first edge of the adjacent material layer at the time of providing the first connection between the material layers, for instance measured in mm, and

d_2 being the distance of the second connection along the second edge of the overlying material layer or along a line parallel thereto from the corresponding edge of the adjacent material layer at the time of providing the second connection between the material layers, for instance measured in mm.

The latter condition is equivalent to the fact that the (partial) circumference - as seen in the cross-section of the tube - of the material layer which serves later as inner

tube between the two material layer connections is larger than the – also seen in the cross-section of the tube – (partial) circumference of an inner layer, which would be the result in the case of two stress-free (between the two material layer connections) concentrically arranged material layers (in a tube shaped according to the manufacturing method according to the present invention). This compared with the
 5 above ratios larger (partial) circumference length between the two material layer connections, then leads to a compression of the inner layer in the circumferential direction and thus to a radial decompression of the inner layer into the outer layer.

According to the geometrical conditions already mentioned in the WO
 10 2006/066814 A1 – depending on the intended pressing force – the size of the elements of the overlying material layer (i.e. of the later inner layer) and the position of the connections between the overlying material layer (i.e. the material layer which later forms the inner layer [or inner tube]) and of the adjacent material layer (i.e. the material layer which later forms the outer layer [or outer tube]) are to be selected.

15 The following overview of the geometrical relationships serves for explanation of the operation here and in particular the origin of the press-force which presses the respective inner material layer against the respective outer material layer:

Hereby in addition to the already introduced variables - preferably in the case of two layers, i.e. one overlying material layer, which provides the inner layer or inner tube
 20 after the tube shaping, and an adjacent material layer, which provides the outer layer or outer tube after the tube shaping - the following variables are also used:

σ_1 as tensile yield strength (which usually roughly corresponds to the compression yield strength, in particular for rolled metals) of the overlying material layer (inner layer), i.e. of the (later) inner tube, given approximately
 25 in N/mm²,

E as modulus of elasticity (Youngs's modulus) of the overlying material layer (inner layer), i.e. of the (later) inner tube, given approximately e.g. in N/mm².

The length of the neutral axis – in the circularly bent state – of the (later) outer tube – designated as ***L_{nfa}*** here - is:

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

corresponding to the average (as seen in the cross-section of the tube) circumference length – here that one of the (later) outer tube – (and thus also to the width of the respective material layer which serves as outer tube). If one wants to fit the inner tube without any compression into the outer tube, the length of its neutral axis (without compression of the inner layer) - here designated as ***L_{nfiOS}*** – would be due to the different bending radii

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

which also corresponds to the average circumference – here however of the inner tube.

If one uses a material layer of the width ***L_{nfiOS}*** as inner layer and a material layer of the width ***L_{nfa}*** as outer layer, the inner layer can fit itself exactly in the outer layer during the tube shaping process, i.e. the respective long edges of the outer layer as well as of the inner layer will about each other at the same time with the termination of the tube shaping process, assuming a geometrically tube shaping process that takes place in an ideal manner, i.e. providing the ideal shaping of a circle (as seen in the cross-section of the tube) . A compression of the inner tube however, which would result in an additional pressing force of the inner tube against the respective outer material layer, due to the pressure built up herewith in the material and due to its bending outwards, would not take place.

But this is exactly what the method according to the invention intends to create. Thus the question arises, which – as seen in the cross-section of the formed tube – (partial) circumference (= width of the overlying material layer before the forming) should the inner layer have for such desired compression of the circumference of

the material layer (B_i) or, what is actually the same, of the width of the overlying material layer in the tube forming process to occur.

According to the above explanations, the length over which the edges of the inner layer relative to those of the outer layer can be freely shifted in the circumferential direction during the tube forming is:

$$L_{fv} = L_{nfa} - L_{nfiOS}$$

and hence

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

which is equivalent to

$$L_{fv} = (SA + SI) \cdot \pi$$

thereby making clear that as a basic principle compression of the respective material layer which serves as inner tube occurs whenever it is wider than the respective material layer which serves as outer layer minus the sum of the thicknesses of both adjacent material layers multiplied by the number π , such that for the width B_i of the material layer which serves as inner tube the following applies:

$$B_i > L_{nfa} - \pi (SA + SI) .$$

However, if the respective material layer which serves as inner tube is compressed in its width in the tube shaping process, namely by both connections provided in accordance with the process according to the present invention, the respective material layer which serves as inner tube due to this is pressed thus also in the respective outer (i.e. outwards adjacent as seen from the inner space of the tube) material layer. Thereby, this pressing force can be increased up to the tensile yield point (respectively compression yield point which usually - especially for rolled sheet metal plates - equals approximately the tensile yield point). In cases in which no distinct tensile- or compression yield points are available, instead the so called technical tensile yield (also referred to as stretch limit as a magnitude of the tension of a plas-

tic remaining stretching under application of a defined force) or technical compression limit can be used as well. Above the zone of so called straight line by Hooke's law, i.e. approximately in the range of the plastic stretching (e.g. in the region of the so called Lüder's band) however, this force cannot be further increased significantly
 5 (at least not proportionally). If therefore with this background in mind one intends to achieve beyond the above-mentioned condition

$$B_i > L_{nfa} - \pi (SA + SI) ,$$

- which basically ensures a compression – a maximum compression and thus a maximum pressing force, the following should be taken into account:

10 The degree of compression of the inner material layer in order to reach the compression yield point – here designated ϵ_{St} – results according to Hooke's law as:

$$\epsilon_{St} = \frac{\sigma_I}{E}$$

According to this, in the case when the maximum pressing force of the inner material layer against the outer material layer is just about to be achieved, the following
 15 applies:

$$B_i - B_i \cdot \epsilon_{St} = L_{nfa} - \pi \cdot (SA + SI) .$$

With respect to the width, resulting for the inner material layer in this case, , thus the following applies:

$$\begin{aligned} B_i &= \frac{L_{nfa} - \pi (SA + SI)}{1 - \epsilon_{St}} \\ &= \frac{L_{nfa} - \pi (SA + SI)}{1 - \frac{\sigma_I}{E}} \end{aligned}$$

20

wherein for the maximized achievable degree of compression $0 < \frac{\sigma_I}{E} < 1$ applies.

For practical purposes it should be noted that – if one wants to achieve the maximized press force of the inner layer against the outer layer in fact in the most reliable (at least to some degree) way, it should be ensured that the compression yield point ($\approx$ tensile yield point) in fact is achieved. This can be achieved if one adds to the maximum degree of compression, as it results on the basis of the material constants, a certain additional offset – which can be generously chosen - preferably of up to 800 % of the maximum degree of compression, in particular preferably of up to 600 % or even up to 300 % or of up to 200 % or even up to 100% of the maximum degree of compression.

Preferably therefore it can be required for practical purposes in order to achieve a pressing force of the inner layer against the outer layer as high as possible, that for the width of the material layer which serves as inner tube in the method of manufacturing of the multi-layer tubes according to the present invention, , the following applies:

$$B_i \geq \frac{L_{nfa} - \pi (SA + SI)}{1 - \frac{\sigma_I}{E}} , \quad \text{with } 0 < \frac{\sigma_I}{E} < 1 .$$

If the width of the inner layer is chosen larger than the term standing right in the equation, a possible compression offset (see above) will be taken into account, which is able to compensate the manufacturing inaccuracies - for example in position and/or in guiding the material layer belts to each other - in such a way that the desired maximum pressure force of the inner tube against the outer tube – at least approximately – is safely achieved.

By adding the compression offset, an elastic widening of the outer tube due to the radially acting press force of the inner tube on the outer tube and influences on the process through any not exactly central position of the neutral axis in the middle of respective material layer after the tube shaping can be compensated.

Above explanations assume however that the compression of the inner layer is provided by the two connections between the material layers, wherein the – seen in the (later) tube cross-section – respective edges of the adjacent material layers which correspond to each other at the time of providing the first and the second connections between the material layers respectively – preferably approximately –flush with each other, and the respective connection is carried out as well – preferably approximately – along the respective edge – preferably by a welding seam along the edge. However, for example, if the second still free edge of the overlying material layer (inner layer) is not drawn so far into the direction of the still free edge of the adjacent material layer (outer layer) that they flush with each other, before – according to this embodiment of the present invention - the second connection is provided, the thus resulting distance **d2** between the second – running along or parallel to the still free (second) edge of the overlying material layer - material layer connection and the corresponding (second) edge of adjacent material layer is also to be taken into account. The same applies accordingly to the distance **d1** of the – running along the or parallel to the other (first) edge of the overlying material layer – first material layer connection from the corresponding (first) edge of adjacent material layer.

Taking this into account, however, the following applies

$$L_{fv} = (SA + SI) \cdot \pi - (d_1 + d_2)$$

and hence:

$$B_i > L_{nfa} - \pi (SA + SI) - (d_1 + d_2),$$

as a condition for a compression. For achieving a maximum compression, the result for **B_i** is accordingly:

$$B_i \geq \frac{L_{nfa} - \pi (SA + SI) - (d_1 + d_2)}{1 - \frac{\sigma_I}{E}}, \quad \text{with } 0 < \frac{\sigma_I}{E} < 1.$$

Preferably, the method for the production of a multi-layer tube according to the present invention is characterized in that the first connection between the material layers is created in such a way that this is done - preferably approximately along one of the longitudinal or transversal edges of the overlying material layer or - preferably approximately – along a line parallel thereto but also along or parallel to the future longitudinal tube seam. The overlying material layer(s) can be parallel with its (their) longitudinal edge to the longitudinal edge of the adjacent (for example underlying) material layer, but this is not necessary. It is also possible that it is (they are) positioned with its (their) longitudinal edge transversely to it. The connection with the adjacent (for example underlying) material layers is done however preferably along or parallel to the future longitudinal seam of the tube.

In this context it should be noted that when in this text a connection along one edge or along one (preferably only imaginary) line is mentioned, hereunder any kind of connection along the edge or line is understood, irrespective whether this connection occurs along the entire edge or line or only in sections along the edge or line or also only in single points (as for example by point welding), for example in two points – preferably in end points of the edge or line – or even only in a single point at the edge or on the line.

The material layer which serves as inner tube can also form, in cross-section, a partial circle in the finished multi-layer tube, which can be achieved by only partially covering the material layer which later provides the outer layer, by the elements of the overlying material layer, which later provide the inner layer of the tube.

Preferably, the material layer which serves as inner tube and forms a partial circle in the finished multi-layer tube thereby forms a groove at the foot of the multi-layer tube.

After finishing of the open seam tube, i.e. after finishing of the – preferably essential – tube shaping process, for example in the bending roller, preferably in the method of high-speed production of a multi-layer tube according to the present invention, the multi-layer tube can be closed by welding of the outer tube along the tube seam.

Preferably this is done also by a deposition welding of the inner tube along the tube seam. Preferably, the body of the multi-layer tube is completed in this way.

Further, the material layers can be connected at the end faces of the tube, for example in order to prevent the ingress of moisture between the metallurgically not
5 full-surface-connected material layers.

A preferred application of the method according to the present invention presents the production of double-layer tubes. However, the invention is not limited to it, also three-, four- and even more-layered tubes according to the invention can hereby be generally produced.

10 In a further particularly preferred embodiment of the present invention, sheets, preferably metal sheets and particularly preferable steel sheets, are used as the material layer or elements of the material layer.

Also in the process for the production of a multi-layer tube according to the present invention, preferably at least one of the connections of the material layers is done as
15 a weld, which is suitable especially for the metal sheets mentioned above, and in particular suitable for steel sheets.

As sheet metal forming machine for example a bending roller, thus for example a three-roller-round-bending machine, but also press-/die arrangement, is suitable, such as those used within the known from the prior art UOE (U-form, O-form, Expansion) tube shaping process (see for the UOE process for example Hiersig, Heinz M., Lexikon Maschinenbau, Heidelberg 1997, S. 704f. regarding the headword „Längsnaht-Großrohrherstellung“) or the so called JCO tube forming process. It is
20 however to be taken into account that according to the method of the present invention – depending on the used material combination – the last step of expansion may have to be omitted if thereby, because of the yield strength ratio of materials from
25 respective inner layer to outer layer, the pressing of the material layers against each other would be deteriorated to much.

In the JCO method the tube is shaped by bringing the sheet metal in a press by means of a sword first in the shape of a lying ,J' and then in the shape of a lying ,C'. Hereafter it is bent in the shape of ,O' as in the case of the UOE process.

5 In the following, non-limiting embodiments are discussed with reference to the drawing. In this is shown:

Fig. 1- 6 a perspective plan view of individual steps of the method for the high-speed manufacturing of a multi-layer tube by means of a sheet metal forming machine, wherein these steps do not necessarily depict all the same shaping process of the same material layers, but show in a schematic manner characteristic steps or stations of the shaping process, and the individual layers of material from step to step respectively from station to station certainly may be others as they can be seen in the preceding or subsequent steps or stations, in order to show variations of the method of the invention on the basis of a series of illustrations in Figures 1 to 6,

15 Fig. 7 a perspective cross-section view through a finished multi-layer tube with the inner layer (also called as inner tube, inner pipe, inner sheet, etc.) and outer layer (also referred to as outer tube, outer pipe, base sheet, etc.),

Fig. 8 a perspective cross-sectional view of a multi-layer tube of Figure 7 with inner layer and outer layer in detail view, in the area of the (welding) connections near the longitudinal weld seam of the tube,

Fig. 9 a situation in the method according to the present invention, when the sheet metal shaping by means of a UO(E) press/die arrangement is performed,

Fig. 10 then the forming step shaping an ,U',

Fig. 11 then the forming step shaping an ,O', i.e. shaping an open seam tube, and

25 Fig. 12 an exemplary stress-strain diagram for explaining how the intended maximum pressing force is achieved by compression of the inner layer with respect to the circumference.

Figure 1 shows a first and second step of an embodiment of the method for the high-speed manufacturing of a multi-layer tube according to the present invention by means of a sheet metal forming machine in a perspective view (the sheet metal forming machine is not shown here).

- 5 In a first step, the single material layers to be combined into a multi-layer tube, namely an overlying material layer 1 and the adjacent material layer 2, are put on top of each other.

In a second step a first connection 3a – preferably a welding connection - between the overlying material layer 1 and the adjacent material layer 2 is then created by
 10 connecting – preferably welded - the overlying material layer 1 with the adjacent material layer 2 – preferably approximately – along a first edge 4a of the overlying material layer 1. The (first) edge 6a of the adjacent material layer 2 which corresponds to the first edge 4a of the overlying material layer lies here displaced outwardly from the first connection 3a of both shown material layers 1, 2, at the distance d_1 – with respect to the overlying material layer 1 and the first edge 4a..
 15 The first connection 3a of the material layers 1, 2 lies also displaced to the inside at the distance d_1 from the (first) edge 6a of the adjacent material layer 2 that corresponds to the first edge 4a of the overlying material layer 1, this with respect to the adjacent (here underlying) material layer 2 and its first edge 6a.

- 20 Figure 2 shows then a third step of the method according to figures 1 to 6, in which the multi-layer material which has been formed in the preceding steps is bent in the area in which the material layers 1, 2 are connected along the edge 4a by the first connection 3a, which can be done for example by means of a bending roller e.g. of a three roller bending machine or by means of a press, e.g. by a press brake, but
 25 also by any other suitable machine or any other suitable tool (also manually). Here, the first edge 4a of the overlying material layer 1 and the corresponding edge 6a of the adjacent material layer 1 flush with each other. The distance d_1 , mentioned in Figure 1, between the first connection 3a of the material layer 1 and 2 and the edge 6a of the adjacent material layer 2, which lies here along both edges 4a and 6b
 30 which flush with each other, is thus equal to zero.

Figure 3 shows then a fourth step of the method according to the present invention corresponding to Figures 1 to 6, wherein here the still free edge 4b of the overlying material layer 1 is moved relative to the adjacent material layer 2 in the direction 10 of the also still free (second) edge 6b. This is preferably done in such a way that this edge 4b is gripped for example by means of a gripping device (not seen here) e.g. by a pair of pliers, which grips the overlying material layer 1 by means of one or more jaws grips (not seen here) and then - e.g. by means of the gripping device - is pulled in the direction 10 of the also still free (second) edge 6b of the adjacent material layer 2. But this can also be done by means of any other machine suitable for this purpose and/or any other tool which is suitable for this purpose (also manually). In principle it is also possible to achieve the intended movement of the material layers 1, 2 and their respective still free (second) edges 4b, 6b to each other according to the invention by shifting the overlying material layer 1 - preferably below - adjacent material layer 2 in the direction of the (second) edge 4b of the overlying material layer 1. Likewise, both edges 4b, 6b can be moved towards each other. It is crucial here that there is a relative movement of the remaining free (second) edge 4b of the material layer 1 to the remaining free (second) edge 6b of the adjacent material layer 2, which reduces the distance between these two still free (respective second) edges 4b, 6b to each other - preferably down to a distance of zero, thus to no remaining distance more. Then, a second connection 3b between the material layers 1, 2 is provided, which lies here along the (second) still free edge 4b of the material layer 1 - preferably as a welding connection, for instance as a welding seam. The distance d_2 between this (second) connection 3b of the material layers to each other and (second) edge 6b of the adjacent (underlying) material layer is here also indicated. The (second) edge 6b of the adjacent material layer 2, which corresponds to the second edge 4b of the material layer 1, lies here on the second connection 3b of the two visible material layers 1, 2 shifted outwardly at the distance d_2 - with respect to the overlying material layer 1 and the second edge 4b.. The second connection 3b of the material layers 1, 2 lies also shifted inwardly - with respect to the adjacent (here underlying) material layer 2 and its (second) edge 6b - at the distance d_2 from the (second) edge 6b of the adjacent material layer 2, which is corresponding to the second edge 4b of the overlying material layer 1.

Figure 4 shows first a fifth step of the method according to Figures 1 to 6, in which two material layers 1, 2 are seen after the previous still free edge 4b of the overlying material layer 1 has been moved - preferably dragged - relative to an adjacent material layer 2 in the direction 10 to the also previously still free edge 6b and in the
5 from this movement eventually resulting position of the material layers 1, 2 relative to each other a second connection 3b - preferably a welded connection, such as a welding seam - between the material layer 1 and the adjacent material layer 2 was created. A first connection 3a was created previously along the first edge 4a of the material layer 1. In the embodiment shown here, the respective corresponding edges
10 4a, 6a on the one hand and 4b and 6b on the other hand of the two material layers 1 and 2 (approximately) lie flush with each other, namely in each case at the line along which each one of the two material layer connections 3a on the one hand and 3b on the other hand have been created. According to the embodiment, as to be seen here, the moving of the previously still free edge 4b of the material layer 1 in
15 direction 10 of the also previously still free edge 6b of the - here underlying - adjacent material layer 2 and the subsequent second connection 3b of the two material layers 1, 2 along the still free edge 4b of the material layer 1 has already generated an arching of the whole future tubular body.

On the other hand, Figure 4 shows also the first step in another embodiment of the
20 method according to the present invention where first the adjacent material layer 2 has been bent, e.g. by means of a bending press for sheet metal panels, such as known from WO 2010/118759 A2, and which allows to already achieve the final radius of the multi-layered tube to be produced in the region of the edges 6a and 6b of the adjacent material layer 2. The bending of the adjacent material layer 2 however,
25 can also be achieved e.g. by pressing the sheet 2 into a correspondingly shaped die, or by simply placing it there, where it receives a bending due to the pressure or by its own weight.

The material layers 1, 2 which are to be combined into the multi-layer tube are put then onto each other, wherein the first material layer 1 as overlying material layer 1
30 is placed on the adjacent material layer 2.

Also, a first connection 3a between the material layer 1 and the adjacent material layer 2 has been created by connecting the overlying material layer 1 to the adjacent material layer 2, approximately along a first edge 4a of the overlying material layer 1. A second connection 3b between the material layer 1 and the adjacent material layer 2 was also created approximately along a second edge 4b of the overlying material layer 1, wherein these connections can be created both in succession as well as - preferably approximately - simultaneously. A (approximately) simultaneous creation of both connections is e.g. possible when the overlying material layer 1 at once - as by means of a suitable conveyor - is positioned - in the correct position on the - then already bent - adjacent material layer 2.

The multi-layer material 1, 2 formed in this way can be shaped then by means of sheet metal forming machine (not shown here) to the multi-layer tube 5, wherein during this forming from a certain degree of shaping of the respective overlaying material layer 1 which serves later as an internal tube is compressed in (partial) circumferential direction - as viewed in cross-section of the (later) (multi-layer) tube - between the two material layer connections 3a, 3b and thus pressed into the adjacent material layer 2 which serves later as outer tube.

Figures 5 and 6 show finally the last step of a preferred embodiment of the method according to the present invention corresponding to Figures 1 to 6, in which the multilayer material formed in the previous steps is shaped by means of the sheet metal forming machine (not seen here) to the tube 5 (more precisely to the open seam tube), namely, to the multi-layer tube (more precisely multi-layer open seam tube), wherein during this shaping, the material layers 1, 2 - due to the previously made connections 3a, 3b - (preferably after specific shaping progress) are compressed between the two connections 3a and 3b in (partial) circumferential direction - seen in the cross-section of the (later) (multi-layer) tube -, so that the respective material layer 1 which serves as an inner tube is pressed - preferably frictionally - into the respective material layer 2 which serves as outer tube.

Figure 7 shows a perspective cross-section through a finished multi-layer tube 5, with an inner layer (e.g. also referred to as material lying inside, material inner layer, inner tube, inner pipe, the inner sheet or the like) 1 and the outer layer (e.g. also

referred to as outer material layer, material outer layer, outer tube, outer pipe, base plate or the like) 2, wherein the multi-layer tube 5 is preferably closed by a weld 7 of the outer tube 2 along a tube seam 8. Preferably for closing the tube, also a deposition welding 9 of the inner tube 1 can be done, as shown here. Such a deposition welding 9 is however not mandatory. The first (weld) connection 3a and the second (weld) connection 3b between the overlying material layer 1 and the adjacent material layer 2 are shown as well.

Figure 8 shows a perspective cross-section through a multi-layer tube according to Figure 7 with an inner layer 1 and outer layer 2 in detailed view in the region of the (weld) connections (e.g. weld seams) 3a, 3b and of the welding (e.g. weld seams or deposition weldings) 7 and 9.

Figure 9 shows a situation of the method according to the invention, when the sheet metal shaping is carried out e.g. by means of a UO(E)-press-die arrangement. The material layer 2 which is later lying outside is here below and the later inner layer 1 above. The upper layer 1 was dragged with its – after the welding of the first connection 3a with the adjacent layer 2 – still free edge 4b in the direction 10 of the also still free edge 6b of the adjacent (here lying below) material layer 2 until the distance of both edges 4b and 6b equaled zero (the edges 4b and 6b thus directly abutted each other) and in this position of the edges 4b and 6b to each other was rim-sided welded with the adjacent – here lying below – material layer 2 along the edge 4b, thus providing a second connection 3b between the material layers 1,2. The dragging over of the first still free edge 4b of the overlying material layer 1 in the direction 10 of the at first also still free edge 6b of the adjacent (lying below) material layer 2 has caused at the same time a bending (be it a plastic bending, be it a elastic bending) at the other end of the material layers 1, 2, namely in the region of the first connection 3a, which again shows that the bending must not be necessarily performed as the first process step.

Figure 10 then shows the shaping step which shapes a 'U', and namely by means of a press (not shown) which downwardly drives a suitably shaped punch 11, where the material layers 1 and 2 are thus driven together in a die (also not to be seen here). The material layer 1 which serves as internal tube is compressed hereby -

preferably after a specific shaping progress - (provided an appropriate width of the inner layer 1) between the two connections 3a, 3b of the material layers 1, 2 and is pressed (force-fitted) into the material layer 2 which serves as outer tube.

Figure 11 shows then the forming step, which forms a ,**O'**, i.e. an open seam tube, and namely by means of a press (not shown here), which drives two semi-circular-shaped punches 12, 13 against the tube body which is to be shaped, where the material layers 1 and 2 thus are driven together to form a round shape - seen in cross-section. Here too, the inner material layer 1 having a corresponding width between the two material layer connections 3a and 3b is compressed and there is pressed into the outer layer 2. Because of the curving, resulting by the way also in other sheet metal forming machines for tube shaping, or tube forming tools, or tube forming methods, e.g. in the tube shaping by means of a bending roller, e.g. a three-roll bending machine, the inner layer 1 does not spring away from the outer layer 2, but it adapts to the outer layer 2.

It should be noted that the method according to the present invention may be carried out in a similar manner by means of a press-die-arrangement adapted for the so-called "JCO" method. Here it is proceeded in accordance with the JCO method, modified however in such a way that again two material layers 1 and 2 are created, similar to the UO(E) method as modified according to the invention. Also here, the overlying material layer 1 is connected with the material layer 2, which later forms the outer layer, at least by two connections 3a, 3b, and then an open seam tube after JCO method is formed. Also here, the desired effect according to the invention occurs in which (preferably after a specific shaping progress), a compression of the inner layer 1 - with a corresponding width - between the two material layer connections 3a and 3b takes place and thus the inner layer 1 is pressed into the outer layer 2.

In all cases, i.e. in particular in the UO(E) process modified according to the present invention as well as in the JCO process modified according to the present invention, the connections 3a and 3b of the two material layers 1 and 2 can be produced by means of a welding - for example by a weld seam.

Figure 12 shows an exemplary stress-strain diagram for explaining how the desired maximum pressing force is achieved by compression of the inner layer along the circumference.

The aim of the present invention is to compress the inner layer material of the multi-layer tube to the extent that the region S in the stress-strain diagram is reached, so as to achieve the maximum possible pressing of the inner layer into the outer layer by the compression, thus to ensure a possibly tight fit of the inner tube within the outer tube.

In the case that the respective material layer which serves as inner tube is compressed in width during the tube shaping - for example by the first and second connection of the two material layers with an accordingly sufficient width B_i of the inner layer -, the respective material layer which serves as inner layer is pressed into the respective outer (i.e. outwards adjacent, as seen from the inner space of the tube) material layer. Thereby, this compressive force can be increased up to the yield point σ_i (respectively compression yield point, which is usually - in particular in rolled metal sheets - approximately equal to the yield point). In cases in which there is no distinctive tensile yield point or compression yield point, instead of this the so-called technical tensile yield (also referred to as stretch limit as an absolute value of the tension of a plastic remaining elongation under a specific load) or technical compression yield can be used. Above the area of the so-called straight line by "Hooke's law" - the region H in the figure - i.e. in the range of plastic strain (e.g. in the region of so-called "Lüder's band") - in this case the region S - however, this force can no longer be significantly increased (at least not more proportional).

The condition

$$B_i > L_{nfa} - \pi (SA + SI) ,$$

or respectively the condition

$$B_i > L_{nfa} - \pi (SA + SI) - (d_1 + d_2) ,$$

if one takes into account the pressing between the two connections between material layers, which lie in distance d_1 and d_2 respectively preferably inwards from the respective edges of the adjacent material layer (i.e. towards the middle of the adjacent material layer) (If the connection is done along the respective edge of the over-
 5 lying material layer and these respectively each flush to its corresponding edge of the adjacent material layer, then the term $d_1 + d_2 = 0$!) insures first of all a compression. If one in addition wants to achieve a maximum compression and hence a maximum press force (due to the compression), the following should be considered:

The degree of compression of the inner material layer for achieving the compression limit - ϵ_{St} here – is resulting from Hooke's law:
 10

$$\epsilon_{St} = \frac{\sigma_I}{E},$$

wherein E is the slope of the straight line known as straight line by Hooke's law in the region H, when there is such (a distinctive straight line by Hooke's law) for the material. Therefore, it applies for the case that the maximum pressing force of the
 15 inner material layer against the outer material layer is just about to be reached that:

$$B_i - B_i \cdot \epsilon_{St} = L_{nfa} - \pi \cdot (SA + SI) .$$

Regarding the width, which results for the strip of the inner material layer in this case, thus applies:

$$\begin{aligned} B_i &= \frac{L_{nfa} - \pi (SA + SI)}{1 - \epsilon_{St}} \\ &= \frac{L_{nfa} - \pi (SA + SI)}{1 - \frac{\sigma_I}{E}} \end{aligned}$$

20

wherein for the maximum achievable degree of compression $0 < \frac{\sigma_I}{E} < 1$ applies.

For practical purposes it has to be considered that – if one actually wants to achieve most reliably at least approximately the maximum press force of the inner layer against to the outer layer – it must be ensured that the compression limit σ_1 ($\approx$ yield strength) is actually achieved. This can be achieved by adding to the maximum degree of compression resulting from the material constants σ_1 and E still a certain offset - preferably up to 800% of the maximum degree of compression, and particularly preferable up to 600% or up to 300% or up to 200% or up to 100% of the maximum degree of compression ϵ_{st} .

Preferably, in the method of manufacturing of multi-layer tubes according to the present invention for the width of the material layer strip which serves as inner tube with respect to achieving a largest possible press force of the inner layer against the outer layer for practical purposes, it can be required that the following applies:

$$B_i > \frac{L_{nfa} - \pi (SA + SI)}{1 - \frac{\sigma_1}{E}} \quad , \quad \text{mit } 0 < \frac{\sigma_1}{E} < 1 .$$

By the fact that the width of the inner layer is thus selected to be larger than the term on the right hand side, a compression offset is taken into account, which is able to compensate the manufacturing inaccuracies – e.g. in the position and/or guiding of the material layer strips to each other – in such a way that the desired maximum press force of the inner tube against the outer tube – at least approximately – is reliably achieved. In this manner, thus for the material of the inner layer the region S is reliably achieved, where the desired maximum pressing force of the inner tube against the outer tube is ensured, since as seen from here – approximately - the maximum rebound force of the inner layer always applies. The compression offsets of 100%, 200% and 300% are put in the diagram for illustration. Similarly, the spring-back path R for 300% compression offset is exemplarily shown in the diagram. It follows that the compressive force arising from the compression of the inner layer in the region S does no longer, at least not significantly, increase.

Considering however the pressing of the material layers against each other in the area between the two material layer connections, which lie at the distance of d_1 and

d_2 from the respective edges of the adjacent material layer preferably inward (i.e. toward the middle of the adjacent material layer), we get for B_i as the width of the inner layer between the two material layer connections:

$$B_i \geq \frac{L_{nfa} - \pi(SA + SI) - (d_1 + d_2)}{1 - \frac{\sigma_I}{E}}, \quad \text{with } 0 < \frac{\sigma_I}{E} < 1$$

- 5 for achieving a maximum press force of the inner layer against the outer layer in the region between both material layer connections. For the compression offset, the already said above also applies here.

Claims

1. Method for the high-speed production of a multi-layer tube (5) by means of a sheet metal forming machine, characterized in that the multi-layer tube (5) comprises at least one first material layer (1) and a second material layer (2) adjacent to the first material layer (1), wherein – not necessarily in the following order -
 - the adjacent material layer (2) is at least slightly bent,
 - the material layers (1,2) to be combined into the multi-layer tube (5) are laid on top of each other, wherein the first material layer (1) is positioned as an overlying material layer on the adjacent material layer (2),
 - 10 - a first connection (3a) between the overlying material layer (1) and the adjacent material layer (2) is created by

connecting the overlying layer (1) with the adjacent material layer (2) approximately along a first edge (4a) of the overlying material layer (1) or approximately along a line parallel thereto,
 - 15 - a second connection (3b) between the overlying material layer (1) and the adjacent material layer (2) is created by

connecting the overlying material layer (1) with the adjacent material layer (2) approximately along a second edge (4b) of the overlying material layer (1) or approximately along a line parallel thereto, and
 - 20 - the thus formed multi-layer material (1,2) is shaped into the multi-layer tube (5) by means of the sheet metal forming machine, wherein

during this shaping process from a certain degree of shaping, the respective overlying material layer (1) which serves then as inner tube is compressed between the two material layer connections (3a, 3b) in (partly) circumferential

direction and is thus pressed into the respective adjacent material layer (2) which serves then as outer tube.

2. Method for the high-speed production of a multi-layer tube (5) according to claim 1, characterized in that the bending of the adjacent material layer (2) along at least one of its edges is carried out already to the end radius of the multi-layer tube (5) to be produced.
3. Method for the high-speed production of a multi-layer tube (5) according to claims 1 or 2, characterized in that
 - the material layers (1,2) to be combined into the multi-layer tube (5) are laid on top of each other,
 - then a first connection (3a) between the overlying material layer (1) and the adjacent material layer (2) is provided by connecting the overlying material layer (1) with the adjacent material layer (2) approximately along the first edge (4a) of the overlying material layer (1) or approximately along a line parallel thereto,
 - whereupon the thus formed multi-layer material is at least slightly bent in the area in which the material layers (1,2) are connected by means of the first connection (3a) approximately along the edge (4a) or along a line approximately parallel thereto, and
 - the second still free edge (4b) of the overlying material layer (1) is positioned relative to the adjacent material layer (2) in a direction of an also still free edge (6b) of the adjacent material layer (2),
 - after that the second connection (3b) between the overlying material layer (1) and the adjacent material layer (2) is created by connecting the overlying material layer (1) with the adjacent material layer (2) approximately along the second still free edge (4b) of the overlying material layer (1) or approximately along a line parallel thereto, and

- the thus formed multi-layer material is shaped into the multi-layer tube (5), by means of the sheet metal forming machine, wherein

during this shaping process, after a certain degree of shaping, the respective overlying material layer (1) which then serves as inner tube is compressed between the two material layer connections (3a, 3b) in (partly) circumferential direction and is thus pressed into the respective adjacent material layer (2) which then serves as outer tube.

4. Method for the high-speed production of a multi-layer tube (5) according to claim 1, 2 or 3, characterized in that the width prior to the tube shaping B_i , of the respective material layer (1) which serves as the inner tube in the region between the two connections (3a, 3b) of the material layers (1, 2), is selected such that

$$B_i > L_{nfa} - \pi (SA + SI) - (d_1 + d_2) ,$$

with B_i being the (partial) circumference (=width before the tube shaping) of the respective material layer (1) which serves as inner tube, as seen in the cross-section of the tube, between the two connections (3a,3b) between the material layers (1,2), preferably given in mm,

L_{nfa} being the circumference (=width before the tube shaping) of the respective material layer (2) which serves as outer tube, as seen in the cross-section of the tube, preferably given in mm,

SA being the wall thickness of the respective material layer (1) which serves as outer tube (2), preferably given in mm,

SI being the wall thickness of the respective material layer which serves as inner tube (1), preferably given in mm, and

d_1 being the distance of the first connection (3a), along the first edge (4a) of the overlying material layer (1) or along a line parallel thereto, from the corresponding first edge (6a) of the adjacent material layer (2), at the time of creation the first connection (3a) between the material layers (1,2), preferably given in mm, and

d₂ being the distance of the second connection (3b) along the second edge (4b) of the overlying material layer (1) or along a line parallel thereto, from the corresponding second edge (6b) of the adjacent material layer (2) at the time of creation the second connection (3b) between the material layers (1,2), preferably given in mm.

5. Method for the high-speed production of a multi-layer tube (5) according to claim 1, 2, 3 or 4, characterized in that the width prior to the tube shaping **B_i**, of the respective material layer (1) which serves as the inner tube, in the region between the two connections (3a and 3b) of the material layers (1, 2) is selected such that

$$10 \quad B_i \geq \frac{L_{nfa} - \pi (SA + SI) - (d_1 + d_2)}{1 - \frac{\sigma_1}{E}}, \text{ with } 0 < \frac{\sigma_1}{E} < 1$$

with **B_i** being the (partial) circumference (=width before the tube shaping) of the respective material layer (1) which serves as inner tube, as seen in the cross-section of the tube, between the two connections (3a, 3b) between the material layers (1, 2), preferably given in mm,

15 **L_{nfa}** being the circumference (=width before the tube shaping) of the respective material layer (2) which serves as outer tube, as seen in the cross-section of the tube, preferably given in mm,

SA being the wall thickness of the respective material layer which serves as outer tube (2), preferably given in mm,

20

SI being the wall thickness of the respective material layer which serves as inner tube (1), preferably given in mm,

σ₁ being the tensile yield point or compression yield point of the overlying material layer (inner layer) (1), as well as of the later inner tube, preferably given in N/mm², and with

25

- E** being the modulus of elasticity (Youngs's modulus) of the overlying material layer (inner layer) (1), i.e. of the (later) inner tube, given preferably in N/mm², and
- d₁** being the distance between the first connection (3a), along the first edge (4a) of the material layer (1) or along a line parallel thereto, from the corresponding first edge (6a) of the adjacent material layer (2) at the time of creation of the first connection (3a) between the material layers (1, 2), preferably given in mm, and
- d₂** being the distance between the second connection (3b), along the second edge (4b) of the material layer (1) or along a line parallel thereto, from the respective second edge (6b) of the adjacent material layer (2) at the time of creation of the second connection (3b) between the material layers (1, 2), preferably given in mm.
6. Method for the high-speed production of a multi-layer tube (5) according to claims 2, 3, 4 or 5, characterized in that the relative movement of the second still free edge (4b) of the material layer (1) to the adjacent material layer (2) in the direction of the also still free edge (6b) of the adjacent material layer (1) is provided by dragging of the overlying material layer (1) on its second still free edge (4b) in the direction of the also still free edge (6b) of the adjacent material layer (2).
7. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 6, characterized in that the first connection (3a) between the material layers (1, 2) is created by connecting the material layers (1, 2) approximately along one of the longitudinal or transverse edges of the material layer (1) or parallel thereto and approximately along or parallel to the future longitudinal tube seam (8).
8. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 7, characterized in that the second connection (3b) between the material layers (1, 2) is created by connecting the material layers (1, 2) approximately along one of the longitudinal or transverse edges of the overlying material layer (1) or parallel thereto and approximately along or parallel to the future longitudinal tube seam (8).

9. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 8, characterized in that the material layer (1) which serves as inner tube in the finished multi-layer tube (5) forms part of a circle as seen in cross-section.
- 5 10. Method for the high-speed production of a multi-layer tube (5) according to claim 9, characterized in that the material layer which serves as the inner tube and forming a part of a circle (1) in the finished multi-layer tube (5), as seen in cross-section, forms a groove at the foot of the multi-layer tube lying on top of each other.
- 10 11. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 10, characterized in that a welding is provided as first (3a) or second (3b) connection between the concentrically arranged material layers (1, 2).
12. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 11, characterized in that the multi-layer tube (5) is closed by a welding (7) of the outer tube (2) along the tube seam (8).
- 15 13. Method for the high-speed production of a multi-layer tube (5) according to claim 12, characterized in that in addition there is a deposition welding (9) of the inner tube (1) along the tube seam (8), carried out from the inside.
14. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 13, characterized in that the material layers (1, 2) are connected at the end faces of the tube (5) - preferably by welding.
- 20 15. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 14, characterized in that a multi-layer tube (5) is manufactured as a double-layer tube.
16. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 15, characterized in that sheets, preferably metal sheets, and more
25 preferably steel sheets are used as the material layers (1, 2).
17. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 16, characterized in that a bending roller is used as sheet metal forming machine.

18. Method for the high-speed production of a multi-layer tube (5) according to claim 17, characterized in that a three-roll-bending machine is used as bending roller.
19. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 16, characterized in that a UO(E) press / die arrangement (13, 14, 15) is
5 used as sheet metal forming machine.
20. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 16, characterized in that a JCO press / die arrangement is used as sheet metal forming machine.