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 welding 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.

This object 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 according to claim 1. Dependent claims correspond to appropriate possible embodiments. According to the method of the present invention, the multi-layer tube comprises at least one first material layer and a material layer adjacent to said first material layer, wherein

- 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,
- 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,

  - a second connection between the overlying material layer and the adjacent material layer is created by

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),

   - 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,

   - after the adjacent material layer (2) is at least slightly bent,

     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 afterwards

   - 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) formed as a single layer 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

- firstly, the adjacent material layer (2) is bent,
- then 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) as overlaying material layer (1) is positioned on the adjacent material layer (2), and

then - consecutively or simultaneously -

- 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,

- a second connection (3b) 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 a second edge (4b) of the overlying material layer (1) or approximately along a line parallel thereto,

and afterwards

- 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 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 moved 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.

5. Method for the high-speed production of a multi-layer tube (5) according to one of the claims 1 to 4, characterized in that the width prior to the tube shaping $\mathbf{B_i}$, 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

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

with $\mathbf{B_i}$ 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,

$\mathbf{L_{nfa}}$ 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

d_2 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.

6. Method for the high-speed production of a multi-layer tube (5) according to of the claims 1 to 5, 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

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

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,

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,

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

σ_I 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/mm^2, and with

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/mm^2, and

d_1 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

d_2 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.

7. Method for the high-speed production of a multi-layer tube (5) according to claim 4 or one of the claims 5 or 6 as far as aforesaid claims refer to claim 4, 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).

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 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).

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 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).

10. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 9, 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.

11. Method for the high-speed production of a multi-layer tube (5) according to claim 10, 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.

12. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 11, characterized in that a welding is provided as first (3a) or second (3b) connection between the concentrically arranged material layers (1, 2).

13. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 12, characterized in that the multi-layer tube (5) is closed by a welding (7) of the outer tube (2) along the tube seam (8).

14. Method for the high-speed production of a multi-layer tube (5) according to claim 13, 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.

15. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 14, characterized in that the material layers (1, 2) are connected at the end faces of the tube (5) - preferably by welding.

16. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 15, characterized in that a multi-layer tube (5) is manufactured as a double-layer tube.

17. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 16, characterized in that sheets, preferably metal sheets, and more preferably steel sheets are used as the material layers (1, 2).

18. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 17, characterized in that a bending roller is used as sheet metal forming machine.

19. Method for the high-speed production of a multi-layer tube (5) according to claim 18, characterized in that a three-roll-bending machine is used as bending roller.

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

21. Method for the high-speed production of a multi-layer tube (5) according to one of claims 1 to 17, characterized in that a JCO press / die arrangement is used as sheet metal forming machine.