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(54) Manufacturing profiles having a cross-section varying in longitudinal direction

(57) The present invention relates to an apparatus for manufacturing a profile (2;2"), the profile (2;2") being made of a single sheet metal (1;1';1"), the apparatus comprising transport means (11) for moving the sheet metal (1) into its longitudinal direction and bending means for bending the sheet metal (1;1") in a bending direction other than the moving direction of the sheet metal (1;1"), the bending means comprising at least to opposing moulded forming rollers (3,3',3",3"',4,4',4",4"';7,7',7",7"',8,8',8",8"',8"",9,9') contacting an upper and lower side of the sheet metal (1;1") directed in-between the opposing moulded forming rollers (3,3',3",3"',4,4',4",4"';7,7',7",7"',8,8',8",8"',8"",9,9') to perform bending operation based on a respective mould of the moulded forming rollers (3,3',3",3"',4,4',4",4"';7,7',7",7"',8,8',8",8"',8"",9,9'), wherein the rotary axis of the moulded forming rollers (3,3',3",3"',4,4',4",4"';7,7',7",7"',8,8',8",8"',8"",9,9') has a constant orientation.

According to the present invention the bending means further comprises at least two opposing transforming rollers (5,5',5",6,6',6"), said transforming rollers (5,5',5",6,6',6") being variably adjustable in the bending direction during bending operation and contacting an upper and lower side of the sheet metal (1') directed in-between the opposing transforming rollers to perform bending operation, and transforming roller orientating means (13) which guarantee a tangential contact between the transforming rollers (5,5',5",6,6',6") and the sheet metal (1') directed in-between the opposing transforming rollers (5,5',5",6,6',6") during bending operation to allow manufacturing of a closed profile (2;2") having a cross section varying in longitudinal direction and consisting of a single sheet metal.

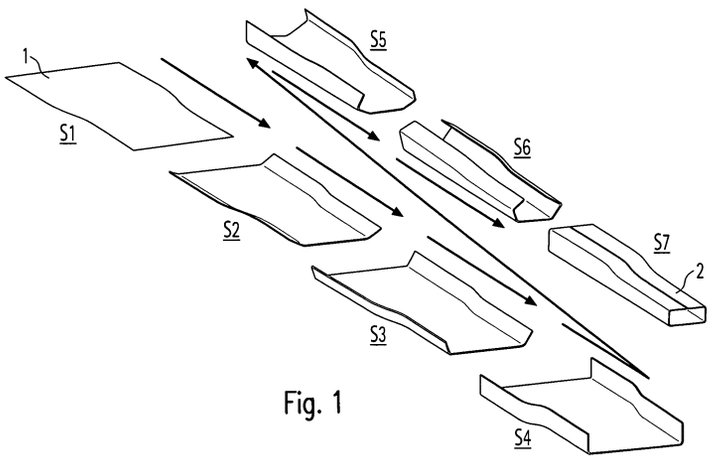

Fig. 1

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Description

[0001] The present invention relates to an apparatus for manufacturing a closed profile having a cross-section varying in longitudinal direction to the use of an apparatus for manufacturing a profile as well as to a method for manufacturing a profile.

[0002] Profiles made of sheet metal (having a thickness of e.g. below 3mm and more preferably below 1mm) are widely used in the prior art, e.g. in manufacturing bumper beams for the automobile industry.

[0003] In the technical field of the production of profiles it is preferred to perform the production of the respective profile by continuously transporting an elongated sheet metal through a production line comprising facilities for bending and/or deep-drawing/stamping.

[0004] The bending facilities comprise bending means for bending the sheet metal in a bending direction other than the moving direction of the sheet metal. The bending means frequently consist of at least two opposing moulded forming rollers contacting an upper and lower side of the sheet metal directed in-between to perform a bending operation based on a respective mould of the forming rollers. The rotary axis of the moulded forming rollers has a constant orientation. To allow bending of sheet metals having different diameters, the distance between the rotary axes of the opposing moulded forming rollers frequently can be adjusted.

[0005] To manufacture open profiles having a cross section varying in longitudinal direction, DE 100 11 755 A1 proposes the use of transforming rollers which are variable adjustable in a bending direction during bending operation. The transforming rollers contact an upper and lower side of the sheet metal directed in-between to perform a bending operation. To avoid unfavourable bending edges between the transforming rollers and the sheet metal DE 100 11 755 A1 additionally discloses the use of transforming roller-orientating means, which guarantee a tangential contact between the transforming rollers and the sheet metal during bending operation.

[0006] It is a disadvantage of the bending apparatus disclosed in DE 100 11 755 A1 that it is not possible to produce closed profiles.

[0007] Deep-drawing/stamping usually is performed by pressing sheet metal into a mould by using a stamp corresponding to the respective mould. In consequence, deep-drawing/stamping usually is not performed continuously but in line with the work cycle of the stamp.

[0008] Both, the above described bending and deep-drawing/stamping operation requires a certain formability of the material used for the sheet metal to achieve a desired geometry. In consequence, it is frequently necessary to simplify the geometry to allow use of a certain material. Especially the use of materials showing a poor formability at room temperature (e.g. magnesium, aluminium and high strength steels) is extremely difficult since these materials tend to rip during deep-drawing/stamping operations.

[0009] Therefore, when processing a sheet metal made of a material showing poor formability at room temperature the radii at bending edges usually have to be significantly more than e.g. 3 times the thickness of the used sheet metal to allow deep-drawing/stamping of the sheet metal.

[0010] Thus, it might be not possible to produce a desired geometry by using a sheet metal made of a material showing poor formability. In this respect, it has to be emphasised that the radii at the bending edges present in a profile significantly influence the stability of the profile. The smaller the radii are, the higher is the stability of the profile.

[0011] Alternatively, the temperature of the sheet metal might be increased during deep-drawing/stamping operation to increase formability of the respective material. For high strength steel a temperature around 900°C is required to significantly increase formability. Aluminium and magnesium require a temperature of between 200°C to 250°C to significantly increase formability.

[0012] This increase of the temperature of the sheet metal during deep-drawing/stamping has the disadvantage that heating means for the sheet metal has to be provided. Said heating means significantly increases the manufacturing costs. Furthermore, immediate further processing of the manufactured parts frequently is not possible, since the manufactured parts have to be cooled down first.

[0013] In consequence, according to the prior art profiles normally are made out of sheet metals consisting of conventional steel having an elongation after fracture A_{80} of more than 15% and thus a good formability at room temperature. In this respect it is noticed that even DE 100 11 755 A1 does not address the problem of bending sheet metals made of materials having a poor formability at room temperature.

[0014] Summarising it is a disadvantage of the prior art that materials showing a poor formability at room temperature cannot be processed. It is a further disadvantage of the prior art techniques that small bending radii cannot be achieved. Moreover, it is a disadvantage of the prior art that closed profiles having a cross section varying in longitudinal direction which consists of a single sheet metal cannot be produced.

[0015] Therefore, it is an object of the present invention to provide a technique for manufacturing a closed profile having a cross section varying in longitudinal direction.

[0016] It is a further object of the present invention to present a technique that allows manufacturing of a profile having a cross section varying in longitudinal direction out of a single sheet metal having poor formability at room

temperature.

[0017] Moreover, it is an object of the present invention to disclose a profile made of sheet metal that has an increased stability.

[0018] The above-mentioned objects are achieved by means of the features of the independent claim.

[0019] Further developments of the central idea of the invention are set forth in the dependent claims.

[0020] Thus, the above object is solved by an apparatus for manufacturing a closed profile having a cross section varying in longitudinal direction, the profile being made of a single sheet metal, the apparatus comprising transport means for moving the sheet metal into its longitudinal direction and bending means for bending the sheet metal in a bending direction other than the moving direction of the sheet metal, the bending means comprising at least to opposing moulded forming rollers contacting an upper and lower side of the sheet metal directed in-between the opposing moulded forming rollers to perform bending operation based on a respective mould of the moulded forming rollers, wherein the rotary axis of the moulded forming rollers has a constant orientation, whereby the bending means further comprises at least two opposing transforming rollers, said transforming rollers being variably adjustable in the bending direction during bending operation and contacting an upper and lower side of the sheet metal directed in-between the opposing transforming rollers to perform bending operation, and transforming roller orientating means which guarantee a tangential contact between the transforming rollers and the sheet metal directed in-between the opposing transforming rollers during bending operation.

[0021] By the inventive combination of moulded forming rollers having a rotary axis with a constant orientation and transforming rollers which are adjustable in the bending direction during bending operation it is possible to manufacture a closed profile having a cross section varying in longitudinal direction by using a single sheet metal, only. In consequence, the number of joining flanges is reduced.

[0022] It has been found by the inventors of the present invention that the inventive apparatus allows manufacturing of a closed profile made of a sheet metal having an elongation after fracture A_{80} of less than 15 %.

[0023] Therefore, the inventive apparatus is especially suitable for processing sheet metal consisting of a material having a poor formability at room temperature. This increased field of application is caused by the surprising effect realised by the inventors that a tangential contact between the transforming rollers and the sheet metal directed in-between during bending operation significantly decreases the occurrence of cracks during bending operation.

[0024] By using a sheet metal having an elongation after fracture A_{80} of less than 15% the stability of the closed profile can be significantly increased.

[0025] It has been found by the inventors that the inventive use of the apparatus disclosed in the preamble of claim 10 allows manufacturing of a profile made of a sheet metal having an elongation after fracture A_{80} of less than 15 % and thus having a poor formability at room temperature.

[0026] This increased field of application is caused by the surprising effect realised by the inventors that a tangential contact between the transforming rollers and the sheet metal directed in-between during bending operation significantly decreases the occurrence of cracks during bending operation.

[0027] Advantageously, the achieved bending radii are three times or less since three times the thickness of the sheet metal used. More preferably, the bending radii in a direction orthogonal to the longitudinal direction of the profile are less than 1.5 times and most preferably less than 1 times the thickness of the sheet metal.

[0028] The production of profiles having small radii in the bending edges further improves stability of the profiles.

[0029] It is preferred that the sheet metal is made of aluminium or magnesium or martensitic steel or a light metal alloy since these materials combine light weight with a high stability.

[0030] Favourably, the resulting profile is at least partially closed. In this case, a sheet metal of rectangular shape can be used and no synchronisation between the position of the sheet metal and the bending operation of the opposing transforming rollers is necessary.

[0031] Alternatively, according to a preferred embodiment of the present invention the resulting profile is completely closed and the used sheet metal is of non-rectangular shape. In this case a synchronisation between the bending operation performed by the opposing transforming rollers and the position of the sheet metal is necessary.

[0032] Moreover, it is preferred that the used sheet metal has a varying thickness to provide a variable strength of the profile.

[0033] In this respect, it is preferred that the thickness of the sheet metal varies about 1% in longitudinal direction and more preferably about 0,5% in longitudinal direction to avoid sudden changes of thickness and thus cracks in the transition area where the thickness changes.

[0034] Moreover, the above object is solved by a profile comprising the features of the preamble of independent claim 18 by the features of the characterising part of claim 18.

[0035] Further developments are set forth in the dependent claims 19, 20 and 24 to 27.

[0036] Thus, according to the present invention a profile having a cross section varying in longitudinal direction is disclosed. The new and inventive profile is made of a singular sheet metal having an elongation after fracture A_{80} of less than 15% and comprises bending radii in a direction orthogonal to the longitudinal direction of the profile that are

three times or less than three times the thickness of the sheet metal.

[0037] More preferably, the bending radii in a direction orthogonal to the longitudinal direction of the profile are less than 1.5 times and most preferably less than 1 time the thickness of the sheet metal.

[0038] The use of sheet metal having an elongation after fracture A_{80} of less than 15% in conjunction with the provision of small radii further increases the stability of the profile.

[0039] According to a first embodiment of the present invention the used sheet metal is of rectangular shape and the resulting profile is at least partially closed.

[0040] According to a second preferred embodiment of the present invention the resulting profile is completely closed and the used sheet metal is of non-rectangular shape.

[0041] Thus, according to the present invention a profile having a cross section varying in longitudinal direction is disclosed, the profile being made of a single sheet metal, wherein the used sheet metal is of non-rectangular shape and the profile is completely closed.

[0042] The inventive use of a single sheet metal being of non-rectangular shape for producing closed profiles having a cross section varying in longitudinal direction allows the production of completely closed profiles having a cross section varying in longitudinal direction.

[0043] To further improve the stability of the profile it is preferred that the profile is made of a sheet metal having an elongation after fracture A_{80} of less than 15%.

[0044] Moreover it is preferred that the bending radii in a direction orthogonal to the longitudinal direction of the profile are three times or less than three times the thickness of the sheet metal to further increase the strength of the profile.

[0045] More preferably, the bending radii in a direction orthogonal to the longitudinal direction of the profile are less than 1.5 times and most preferably less than 1 time the thickness of the sheet metal.

[0046] It is further preferred that the sheet metal has an elongation after fracture A_{80} of less than 13% and more preferably of less than 10%.

[0047] In consequence, the inventive profile might be made of a sheet metal consisting of aluminium or magnesium or martensitic steel or a light metal alloy.

[0048] Preferably, the used sheet metal has a varying thickness to account for varying requirements for strength of the profile.

[0049] In this respect it is preferred that the thickness of the sheet metal varies about 1% in longitudinal direction and more preferably about 0,5% in longitudinal direction.

[0050] Further, the above object is solved by a method of manufacturing a profile having a cross section varying in longitudinal direction, the profile being made of a sheet metal, the methods comprising the features of the preamble of independent claim 32 by the feature of the characterising proportion of independent claim 32.

[0051] By applying the inventive method it is possible to manufacture profiles made of sheet metal consisting of a material having a poor formability at room temperature.

[0052] In this respect it is preferred that the method is performed at a temperature below 100°C and more preferably below 50°C and most preferably below 30°C. Thus, the manufacturing costs can be significantly reduced since only a minor or even no heating of the sheet metal during bending operation is necessary.

[0053] In the following detailed description, the present invention is explained by reference to the accompanying drawings, in which like reference characters refer to like parts throughout the views, wherein:

Figure 1	schematically shows different bending steps when manufacturing a closed profile having a cross section varying in longitudinal direction;
Figures 2A, 2B	show a first bending step using a first section of the inventive apparatus for manufacturing a closed profile;
Figures 3A, 3B	show a second bending step when manufacturing a closed profile by using a second section of the inventive apparatus for manufacturing a closed profile;
Figures 4A, 4B	show a third bending step when manufacturing a closed profile by using a third section of the inventive apparatus for manufacturing a closed profile;
Figures 5A, 5B, 5C and 5D	show different examples of profiles manufactured by the inventive apparatus for manufacturing a profile;
Figure 6	shows the second bending step of manufacturing a closed profile by using the second section of the inventive apparatus in more detail; and

Figure 7 shows bending means used in the second bending step of manufacturing a closed profile in detail; and

Figures 8A, 8B illustrate a preferred use of a profile manufactured by the inventive apparatus.

[0054] Figure 1 schematically shows sequential bending steps performed by the inventive apparatus for the manufacturing of a closed profile 2 by bending a single sheet metal 1. The inventive apparatus for manufacturing a closed profile will be described in more detail with reference to figures 2 to 4B, 6 and 7.

[0055] In the present example, the sheet metal 1 consists of martensitic steel or other... and thus has an elongation after fracture A_{80} of less than 10%. Alternatively, said sheet metal 1 may consist of aluminium, magnesium or a light metal alloy having an elongation after fracture A_{80} of less than 15%, more preferably less than 13% and most preferably less than 10%, respectively.

[0056] As it is shown in figure 1, the manufacturing of a closed profile 2 having a cross section varying in longitudinal direction by using a single sheet metal requires the processing of a sheet metal 1 having a suitable non-rectangular shape.

[0057] In a first step S 1 the sheet metal 1 is directed in a longitudinal direction.

[0058] In a second step S2 parts of the sheet metal 1 that will form the top of the closed profile 2 are bent upwards in a first bending step by using a second section of the inventive apparatus for manufacturing a closed profile. A synchronisation between the bending operation and the position of the sheet metal is necessary due to the non-rectangular shape of the sheet metal 1.

[0059] In the following step S3 said parts of the sheet metal 1, which will form the top of the closed profile 2, are further bent by using the second section of the inventive apparatus for manufacturing a closed profile till bending of said parts is completed in step S4.

[0060] In the following step S5 a third section of the inventive apparatus for manufacturing a closed profile is used to bend parts that will form the sidewalls of the closed profile 2.

[0061] Said bending operation is continued in step S6 till the sidewalls are completely formed and the profile 2 is closed (step S7).

[0062] To further increase the strength of the profile it is preferred that the bending radii in a direction orthogonal to the longitudinal direction of the profile 2 are three times and more preferably less than three times the thickness of the sheet metal 1 used.

[0063] Bending radii in a direction orthogonal to the longitudinal direction of the profile which are even less than 1.5 times and most preferably less than 1 time the thickness of the sheet metal 1 are preferred.

[0064] Thus, by the above-described bending operation it is possible to produce a completely closed profile having a cross section varying in longitudinal direction, the profile 2 being made of a single sheet metal 1.

[0065] Figures 2A, 2B, 3A, 3B, 4A, 4B show a preferred embodiment of the inventive apparatus for manufacturing a closed profile out of a single sheet metal which is capable to perform the above described bending operations.

[0066] In this respect it has to be emphasised that figures 2A, 3A and 4A show a first, second and third section of the inventive apparatus, respectively. Said first, second and third sections are arranged in a row. Where applicable, succeeding sections may be interconnected by transportation means (which are not shown in the figures) for transporting the sheet metal in a longitudinal direction from a preceding section to a succeeding section. Furthermore, buffer storages (which are not shown in the figures) might be arranged between succeeding sections.

[0067] Furthermore, in this preferred embodiment the apparatus consists of two identical arrangements that are arranged opposing one another with respect to a longitudinal direction of the sheet metal. For sake of clearness of the figures, only one of the opposing arrangements is shown in the figures 2A, 3A and 4A.

[0068] Moreover, for the sake of simplicity, figures 2A, 3A and 4A do not show the sheet metal directed in-between the opposing transforming rollers, but the sheet metal before and after bending operation, only.

[0069] As shown in figure 2A, a first section of the inventive apparatus for manufacturing a closed profile 2" having a cross section varying in longitudinal direction out of a single sheet metal 1; 1'; 1" comprises transport means 11.

[0070] The transport means 11 consists of two opposing rollers driven in reverse directions by a motor, which is not shown in the figure. By guiding the sheet metal 1 in-between the rollers, the transport means 11 moves the sheet metal 1 into its longitudinal direction. The distance between the axes of rotation of the opposing rollers is adjustable to account for different thicknesses of sheet metal 1. In this respect it is advantageously if at least some of the opposing rollers have at least some elasticity regarding the gap in-between the opposing rollers.

[0071] The moved sheet metal 1 passes in-between first bending means for bending the sheet metal 1 in a bending direction other than the moving direction of the sheet metal 1.

[0072] In the preferred embodiment shown in figure 2A, said first bending means comprise four pairs of opposing moulded forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"'. The moulded forming rollers have a shape which allows bending of the sheet metal 1 directed in-between the opposing moulded forming rollers. Furthermore, the opposing moulded

forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"' are arranged in a way to allow a linear movement of the sheet metal 1 in-between the opposing moulded forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"' to avoid unnecessary bending of the sheet metal 1.

[0073] The opposing moulding forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"' contact an upper and lower side of the sheet metal 1 directed in-between the opposing moulded forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"'. In consequence, the sheet metal 1 takes up the outer shape of the opposing moulded forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"'. Thus, with the first bending means shown in figure 2A, the bending operation is caused by the outer shape of the opposing moulding forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"'.

[0074] In the present embodiment, driving means (not shown) are provided to rotate opposing moulded forming rollers in reverse direction, respectively. Thus, in figure 2A the upper moulded forming rollers 3, 3', 3", 3"' are rotated clockwise while the lower moulded forming rollers 4, 4', 4", 4"' are rotated counter clockwise.

[0075] Furthermore, the distance of the respective axis of rotation of the opposing moulded forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"' is adjustable to account for different thicknesses of sheet metal 1 and to vary the pressure applied to the sheet metal 1 during bending operation. Even some elasticity regarding the gap in-between the opposing rollers might be provided.

[0076] In this respect it has to be emphasised that the axis of rotation of the moulded forming rollers has a constant orientation, respectively.

[0077] As said above, figure 2A shows only half of the first bending means necessary to produce the bent sheet metal 1' shown in figure 2A.

[0078] To provide a better understanding of the bending operation performed by the moulded forming rollers of the first bending means, figure 2B shows the different steps of the bending operation. Bending is performed in the direction of arrow A. Thus, bending is not performed in one single step but sequentially by succeeding opposing moulded forming rollers 3, 4, 3', 4', 3", 4", 3"', 4"' to reduce the stress applied onto the sheet metal 1.

[0079] Figures 3A and 3B show a second section of the inventive apparatus for manufacturing a closed profile 2".

[0080] To allow manufacturing of a closed profile 2" having a cross section varying in longitudinal direction by bending a single sheet metal 1, the apparatus shown in figures 2A, 3A, 4A further comprises second bending means.

[0081] In this preferred embodiment said second bending means consist of six pairs of opposing transforming rollers 5, 6, 5', 6', 5", 6". For sake of clearness of figure 3A not for each single transforming roller a reference sign is provided.

[0082] The opposing transforming rollers 5, 6, 5', 6', 5", 6" are variably adjustable in a bending direction during bending operation and contact an upper and lower side of the sheet metal 1' directed in-between the opposing transforming rollers 5, 6, 5', 6', 5", 6" to perform bending operation.

[0083] According to the present invention, the second bending means further comprises transforming roller orientating means 13 (not shown in figure 3A) which guarantee a tangential contact between the transforming rollers 5, 6, 5', 6', 5", 6" and the sheet metal 1' directed in-between the opposing transforming rollers 5, 6, 5', 6', 5", 6" during bending operation.

[0084] For a better understanding of the function and construction of the opposing transforming rollers 5, 6, 5', 6', 5", 6" and the corresponding transforming roller orientating means 13 the function thereof is further explained by reference to figures 6 and 7.

[0085] The arrows shown in figure 6 illustrate the different orientations and movement operations which might be performed by the opposing transforming rollers 5, 6, 5', 6', 5", 6" during bending operation.

[0086] In figure 6, the opposing moulded forming rollers 3"" and 4"" still are part of first bending means. Thus, in contrast to the orientation of the axis of rotation of the opposing transforming rollers 5, 6, 5', 6', 5", 6" the orientation of the axis of rotation of the opposing moulded forming rollers 3"" and 4"" can not be changed during bending operation.

[0087] As it is shown in figure 6, the opposing transforming rollers 5, 6, 5', 6', 5", 6" might be moved in a direction orthogonal to the longitudinal direction of the sheet metal 1' during bending operation.

[0088] Furthermore, the bending direction of the opposing transforming rollers 5, 6, 5', 6', 5", 6" might be varied during bending operation by inclining the respective axis of rotation of the opposing transforming rollers 5, 6, 5', 6', 5", 6".

[0089] Moreover, to avoid an adverse deformation of the sheet metal 1' during bending operation, each pair of opposing transforming rollers 5, 6, 5', 6', 5", 6" automatically is orientated by transforming roller orientating means 13 in a way that guarantees a tangential contact between the opposing transforming rollers 5, 6, 5', 6', 5", 6" and the sheet metal 1' directed in-between during bending operation.

[0090] Figure 7 shows in more detail a suitable arrangement of opposing transforming rollers 5,6.

[0091] A slide 14b is movable in a direction orthogonal to the longitudinal direction of the sheet metal 1 by rotating a threaded bar 14a which is engaged with the slide 14b.

[0092] The slide 14b rotatably supports a turning knob 16, the turning knob 16 being rotated by transforming roller orientating means 13. In the present example, said transforming roller-orientating means 13 is an electric motor actuated in dependency on a movement of the slide 14b.

[0093] The turning knob 16 supports transporting means 11'. The transporting means 11' comprises at least one

roller which is rotated by an electric motor to move a sheet metal (not shown) located in-between the opposing rollers in a longitudinal direction. Alternatively, the opposing rollers might be used. Further alternatively, the transporting mean might be avoided.

[0094] Furthermore, the turning knob 16 supports two opposing transforming rollers 5, 6. The opposing transforming rollers 5, 6 are hold by bending direction-orientating means 15 that allows an adjustment of the bending direction of the opposing transforming rollers 5, 6. In the present embodiment, said bending direction orientating means 15 are provided by a gear wheel and a gear rack arrangement 15, wherein the gear rack is a arcuated semi circular. The gear wheel and a gear rack arrangement 15 are actuated by a motor (not shown).

[0095] Furthermore, the distance of the axis of rotation of the opposing transforming rollers 5, 6 is adjustable by means of a screw 17 to adapt to different thicknesses of sheet metal directed in-between the opposing transforming rollers 5, 6. Furthermore, a spring might be additionally provided to achieve some elasticity regarding the gap in-between the opposing transforming rollers5, 6. Rotation of the threaded bar 1a and actuation of the electric motor of the transforming roller orientating means 13 and of the motor driving the gear wheel and gear rack arrangement 15 might be catrilled by a microcontroller.

[0096] To provide a better understanding of the bending operation performed by the opposing transforming rollers of the second bending means, figure 3B shows the different steps of the bending operation. Bending is performed in the direction of arrow A'. It is important to emphasise that only a part of the sheet metal 1" is bent the way shown by arrow A'. A part of the sheet metal 1" might not be bent at all.

[0097] It is noted that figure 3A shows only half of the second bending means necessary to produce the bent sheet metal 1" shown in figures 3A and 3B.

[0098] Figure 4A shows a third section of the inventive apparatus for manufacturing a closed profile 2'. In the third section, the pre-bent sheet metal 1" is driven through a further set of opposing moulded forming rollers 7, 8, 7', 8', 7", 8", 7"', 8"'. Said further set of opposing moulded forming rollers basically corresponds to the first bending means described with respect to figure 2A.

[0099] Furthermore, additional bending rollers 9, 9' that are not moulded are provided. The bending operation of said additional bending rollers 9, 9' bases on an orthogonal pressure applied onto the pre-bent sheet metal 1".

[0100] As it is shown in figure 4A, it is possible to combine a moulded forming roller 8"" and an additional bending roller 9' where applicable. It is evident that the axis of rotation of the opposing moulded forming roller 8"" and of the additional bending roller 9' does not have to be parallel as long as the sheet metal 1" is conducted in-between the rollers to perform bending operation.

[0101] Once again, the respective axis of rotation of the rollers 7, 8, 7', 8' 7", 8", 7"', 8"', 8"", 9, 9' have a constant orientation. Only the distance between the respective axes of opposing rollers might be varied to allow adjustment of the bending arrangement to different thicknesses of sheet metal 1". Furthermore, the opposing rollers may have some elasticity regarding the gap in-between the opposing rollers.

[0102] Figure 4B shows the effect the above described third section of the inventive apparatus for manufacturing a closed profile 2' has on a sheet metal 1".

[0103] It is evident that the arrangement allows the production of a closed profile having a cross section varying in longitudinal direction, wherein the profile 2' is made of a single sheet metal.

[0104] Although figure 4B shows a much larger bending radius δ, it is preferred that the bending radius achieved by the inventive apparatus is three times or less than three times or more preferably less than 1.5 times or most preferably less than 1 time the thickness of the sheet metal 1.

[0105] Although concrete numbers of rollers have been described above with respect to the inventive apparatus, it is evident that said number of rollers might be varied in any suitable way.

[0106] Figures 5A, 5B, 5C and 5D show different profiles manufactured by the inventive apparatus.

[0107] When using a single sheet metal 1 being of rectangular shape, the resulting profile 2', 2"', 2"" is at least partially closed at it is shown in figures 5A, 5C and 5D.

[0108] When using a single sheet metal 1 being of non-rectangular shape, it is possible to produce a profile 2, 2", which is completely closed as shown in figures 1 and 5B.

[0109] Due to the high strength of the above-described profiles, the above-described profiles are especially suitable for the production of parts for the automobile industry, e.g. bumper beams as it is shown in figures 8A and 8B.

[0110] It is well understood by a person skilled in the art that the used sheet metal 1 may have a varying thickness in longitudinal direction. To avoid areas which tend to crack due to a rapid variation in thickness of the material it is preferred that the thickness of the sheet metal 1 varies less than about 1% in longitudinal direction and more preferably less than about 0,5% in longitudinal direction.

[0111] When studying the inventive apparatus for manufacturing a closed profile, the inventor has recognised that the above-described apparatus allows manufacturing of a profile made of a sheet metal having an elongation after fracture A_{80} of less than 15%. This is very surprising since a sheet metal having an elongation after fracture A_{80} of less than 15% is only bad deformable without heating.

[0112] In this respect it has been recognised that even sheet metals having an elongation after fracture A_{80} of less than 13% or less than 10% may be used. Possible sheet metals consist of aluminium or magnesium or martensitic steel or a light metal alloy, for example.

[0113] Thus, according to the present invention it is possible to manufacture a profile having a cross section varying in longitudinal direction, the profile being made of a single sheet metal having an elongation after fracture A_{80} of less than 15%, wherein the bending radii δ in a direction orthogonal to the longitudinal direction of the profile are three times or less than three times the thickness of the sheet metal. It is even possible to realise bending radii δ in a direction orthogonal to the longitudinal direction of the profile, which are less than 1.5 times, and most preferably less than 1 time the thickness of the sheet metal.

[0114] To produce closed profiles made of a sheet metal having an elongation after fracture A_{80} of less than 15%, so far it has been necessary to either use bending radii larger than three times the thickness of the used sheet metal or to manufacture the closed profile by compounding at least two sheet metals. Compounding a profile out of two sheet metals increases the number of joining flanges. This is avoided by the present invention.

[0115] Furthermore, to bend sheet metal consisting of a material having elongation after fracture A_{80} of less than 15%, it has so far been necessary to heat the material before performing the bending operation. This is overcome by the present invention which allows to perform bending operation of said sheet metals below 100°C or more preferably below 50°C or most preferably below 30°C and thus even at room temperature without any heating.

Claims

1. Apparatus for manufacturing a closed profile (2; 2") having a cross section varying in longitudinal direction, the profile (2; 2") being made of a single sheet metal (1; 1'; 1"), the apparatus comprising:

   - transport means (11) for moving the sheet metal (1) into its longitudinal direction; and
   - bending means for bending the sheet metal (1; 1") in a bending direction other than the moving direction of the sheet metal (1; 1"), the bending means comprising at least to opposing moulded forming rollers (3, 3', 3", 3"', 4, 4', 4", 4"'; 7, 7', 7", 7"', 8, 8', 8", 8"', 8"", 9, 9') contacting an upper and lower side of the sheet metal (1; 1") directed in-between the opposing moulded forming rollers (3, 3', 3", 3"', 4, 4', 4", 4"'; 7, 7', 7", 7"', 8, 8', 8", 8"', 8"", 9, 9') to perform bending operation based on a respective mould of the moulded forming rollers (3, 3', 3", 3"', 4, 4', 4", 4"'; 7, 7', 7", 7"', 8, 8', 8", 8"', 8"", 9, 9'), wherein the rotary axis of the moulded forming rollers (3, 3', 3", 3"', 4, 4', 4", 4"'; 7, 7', 7", 7"', 8, 8', 8", 8"', 8"", 9, 9') has a constant orientation;

   characterising in that the bending means further comprises

   - at least two opposing transforming rollers (5, 5', 5", 6, 6', 6"), said transforming rollers (5, 5', 5", 6, 6', 6") being variably adjustable in the bending direction during bending operation and contacting an upper and lower side of the sheet metal (1') directed in-between the opposing transforming rollers to perform bending operation, and
   - transforming roller orientating means (13) which guarantee a tangential contact between the transforming rollers (5, 5', 5", 6, 6', 6") and the sheet metal (1') directed in-between the opposing transforming rollers (5, 5', 5", 6, 6', 6") during bending operation.

2. Apparatus according to claim 1,
   characterised in that
   the sheet metal (1; 1'; 1") has an elongation after fracture A_{80} of less than 15 %.

3. Apparatus according to claim 1 or 2,
   characterised in that
   the sheet metal (1; 1'; 1") has an elongation after fracture A_{80} of less than 13 % or less than 10 %.

4. Apparatus according to one of the preceding claims,
   characterised in that
   the bending radius (δ) achieved by the apparatus is three times or less than three times or more preferably less than 1.5 times or most preferably less than 1 time the thickness of the sheet metal (1; 1'; 1").

5. Apparatus according to one of the preceding claims,
   characterised in that
   the sheet metal (1; 1'; 1") is made of aluminium or magnesium or martensitic steel or a light metal alloy.

6. Apparatus according to one of the preceding claims,
characterised in that
the used sheet metal (1; 1'; 1") is of rectangular shape and the resulting profile (2'; 2"'; 2"") is at least partially closed.

7. Apparatus according to anyone of the claims 1 to 5,
characterised in that
the used sheet metal (1; 1'; 1") is of non-rectangular shape and the resulting profile (2; 2") is completely closed.

8. Apparatus according to one of the preceding claims,
characterised in that
the used sheet metal (1; 1'; 1") has a varying thickness.

9. Apparatus according to claim 8,
characterised in that
the thickness of the sheet metal (1; 1'; 1") varies about 1 % in longitudinal direction or about 0.5 % in longitudinal direction.

10. Use of an apparatus for manufacturing a profile (2; 2'; 2"; 2"'; 2"") having a cross section varying in longitudinal direction, the profile (2; 2'; 2"; 2"'; 2"") being made of a sheet metal (1; 1'; 1"), the apparatus comprising:

- transport means (11) for moving the sheet metal (1; 1'; 1") into its longitudinal direction;
- bending means for bending the sheet metal (1; 1'; 1") in a bending direction other than the moving direction of the sheet metal (1; 1'; 1"),
  wherein the bending means comprise at least two opposing transforming rollers, said transforming rollers (5, 5', 5", 6, 6', 6") being variably adjustable in the bending direction during bending operation and contacting an upper and lower side of the sheet metal (1') directed in-between the opposing transforming rollers (5, 5', 5", 6, 6', 6") to perform bending operation,
  the bending means further comprising transforming roller orientating means (13) which guarantee a tangential contact between the transforming rollers (5, 5', 5", 6, 6', 6") and the sheet metal (1') directed in-between the opposing transforming rollers (5, 5', 5", 6, 6', 6") during bending operation,

characterising in that
the apparatus is used for manufacturing a profile (2; 2'; 2"; 2"'; 2"") made of a sheet metal (1; 1'; 1") having an elongation after fracture A_{80} of less than 15 %.

11. Use of an apparatus according to claim 10,
characterised in that
the sheet metal (1; 1'; 1") has an elongation after fracture A_{80} of less than 13 % or less than 10 %.

12. Use of an apparatus according to claim 10 or 11,
characterised in that
the bending radius (δ) achieved by the apparatus is three times or less than three times or more preferably less than 1.5 times or most preferably less than 1 time the thickness of the sheet metal (1; 1'; 1").

13. Use of an apparatus according to anyone of claims 10, 11 or 12,
characterised in that
the sheet metal (1; 1'; 1") is made of aluminium or magnesium or martensitic steel or a light metal alloy.

14. Use of an apparatus according to anyone of claims 10, 11, 12 or 13,
characterised in that
the used sheet metal (1; 1'; 1") is of rectangular shape and the resulting profile (2'; 2"', 2"") is at least partially closed.

15. Use of an apparatus according to anyone of claims 10, 11, 12 or 13,
characterised in that
the used sheet metal (1; 1'; 1") is of non-rectangular shape and the resulting profile (2; 2") is completely closed.

16. Use of an apparatus according to anyone of claims 10 to 15,
characterised in that

the used sheet metal (1; 1'; 1") has a varying thickness.

17. Use of an apparatus according to claim 16,
characterised in that
the thickness of the sheet metal (1; 1'; 1") varies about 1 % in longitudinal direction or about 0.5 % in longitudinal direction.

18. Profile (2; 2'; 2"; 2'''; 2'''') having a cross section varying in longitudinal direction, the profile being made of a single sheet metal (1; 1'; 1") having an elongation after fracture A_{80} of less than 15 %,
characterised in that
the bending radii (δ) in a direction orthogonal to the longitudinal direction of the profile (2; 2'; 2"; 2'''; 2'''') are three times or less than three times or more preferably less than 1.5 times or most preferably less than 1 time the thickness of the sheet metal (1; 1'; 1").

19. Profile according to claim 18,
characterised in that
the used sheet metal (1; 1'; 1") is of rectangular shape and the resulting profile (2'; 2'''; 2'''') is at least partially closed.

20. Profile according to claim 18,
characterised in that
the used sheet metal (1; 1'; 1") is of non-rectangular shape and the resulting profile (2; 2") is completely closed.

21. Profile having a cross section varying in longitudinal direction,
the profile (2; 2") being made of a single sheet metal (1; 1'; 1"),
characterised in that
the used sheet metal (1; 1'; 1") is of non-rectangular shape and the profile (2; 2") is completely closed.

22. Profile according to claim 21,
characterised in that
the profile (2; 2") is made of a single sheet metal (1; 1'; 1") having an elongation after fracture A_{80} of less than 15 %.

23. Profile according to claim 21 or 22,
characterised in that
the bending radii (δ) in a direction orthogonal to the longitudinal direction of the profile (2; 2") are three times or less than three times or more preferably less than 1.5 times or most preferably less than 1 time the thickness of the sheet metal (1; 1'; 1").

24. Profile according to anyone of claims 18 to 23,
characterised in that
the sheet metal (1; 1'; 1") has an elongation after fracture A_{80} of less than 13 % or less than 10 %.

25. Profile according to anyone of claims 18 to 24,
characterised in that
the sheet metal (1; 1'; 1") is made of aluminium or magnesium or martensitic steel or a light metal alloy.

26. Profile according to anyone of claims 18 to 25,
characterised in that
the used sheet metal (1; 1'; 1") has a varying thickness.

27. Profile according to claim 26,
characterised in that
the thickness of the sheet metal (1; 1'; 1") varies about 1 % in longitudinal direction or about 0.5 % in longitudinal direction.

28. A method for manufacturing a profile (2; 2'; 2"; 2'''; 2'''') having a cross section varying in longitudinal direction, the profile (2; 2'; 2"; 2'''; 2'''') being made of a sheet metal (1; 1'; 1"),
the method comprising the steps of:

- moving the sheet metal (1; 1'; 1") into its longitudinal direction;
- bending the sheet metal in a bending direction other than the moving direction of the sheet metal (1; 1'; 1") by directing the sheet metal (1; 1'; 1") in-between at least two opposing transforming rollers (5, 5', 5", 6, 6', 6"), the opposing transforming rollers (5, 5', 5", 6, 6', 6") being variably adjustable in the bending direction during bending operation and contacting an upper and lower side of the sheet metal (1; 1'; 1"), respectively, wherein the transforming rollers (5, 5', 5", 6, 6', 6") automatically are orientated in a way to guarantee a tangential contact between the transforming rollers (5, 5', 5", 6, 6', 6") and the sheet metal (1; 1'; 1") during bending operation,

characterising in that
a profile made of a sheet metal (1; 1'; 1") having an elongation after fracture A_{80} of less than 15 % is used.

29. A method according to claim 28,
characterised in that
it is performed at a temperature below 100°C or below 50°C or below 30°C.

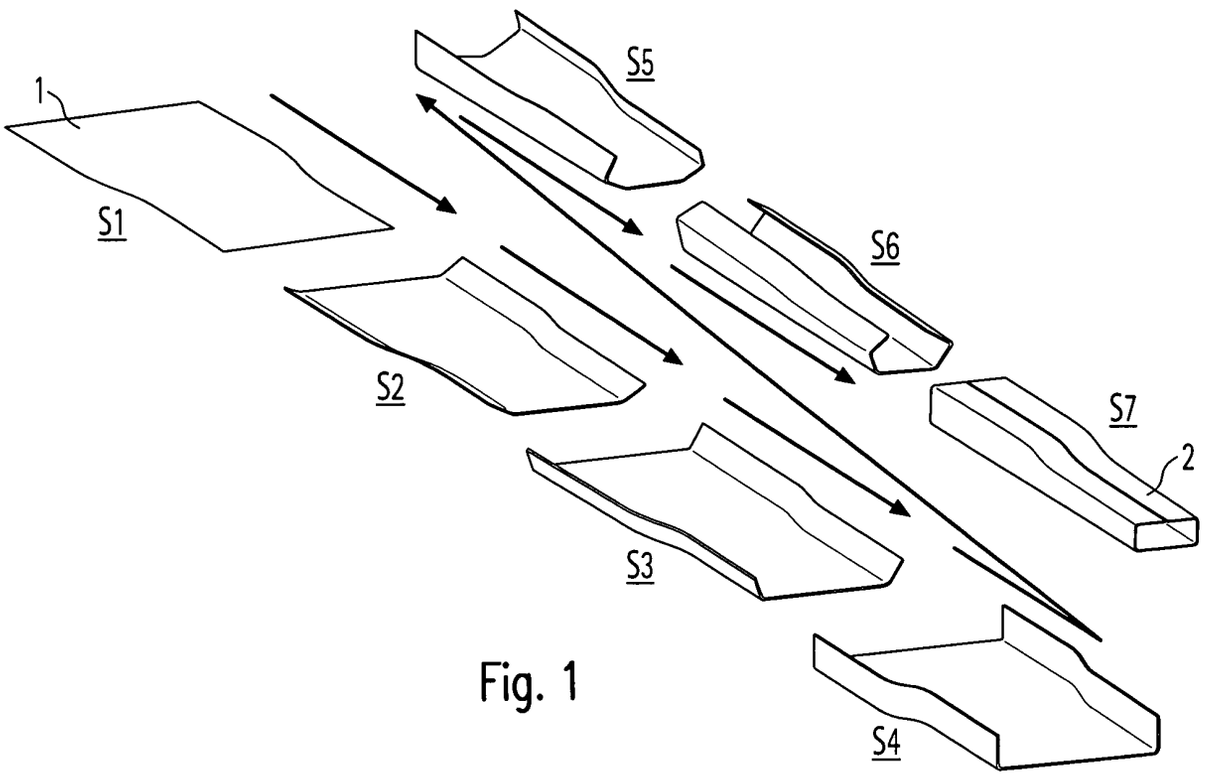

Fig. 1

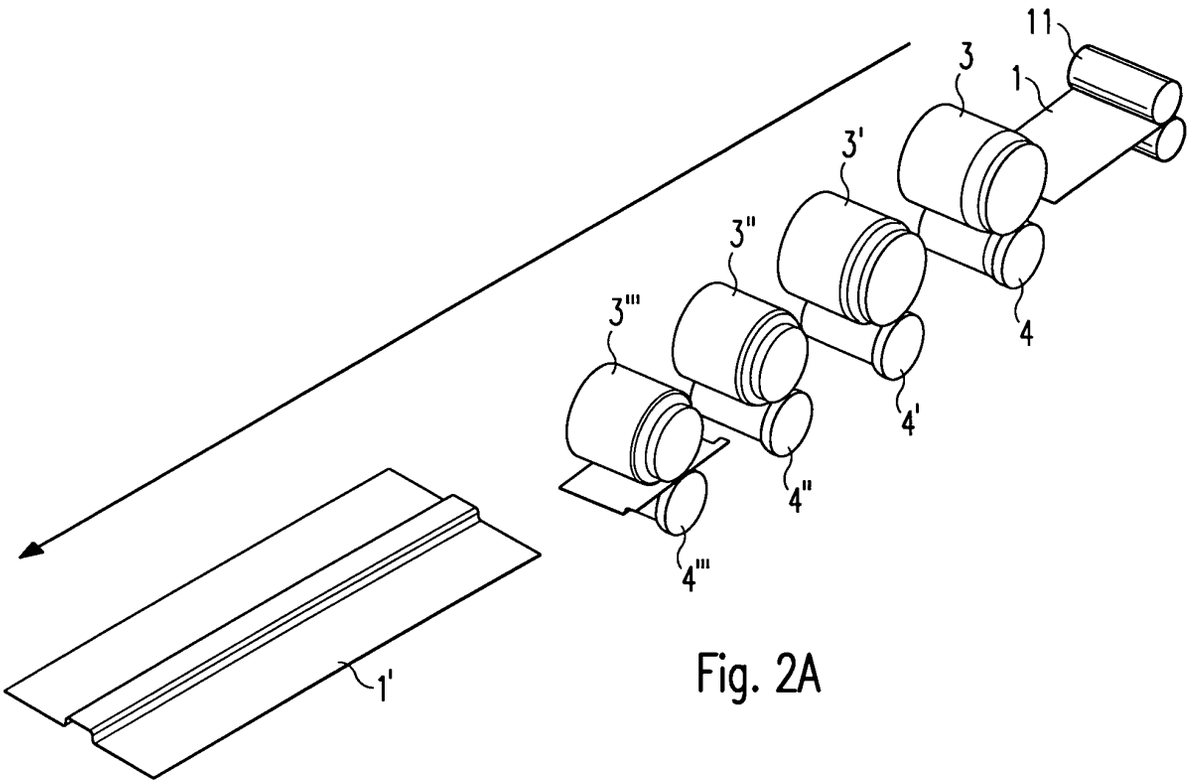

Fig. 2A

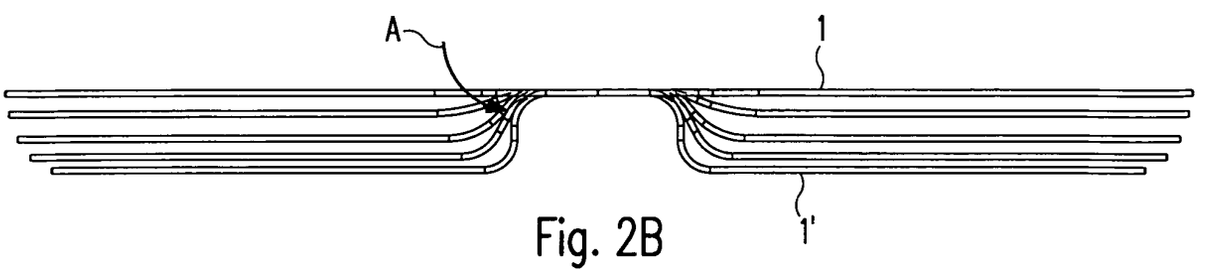

Fig. 2B

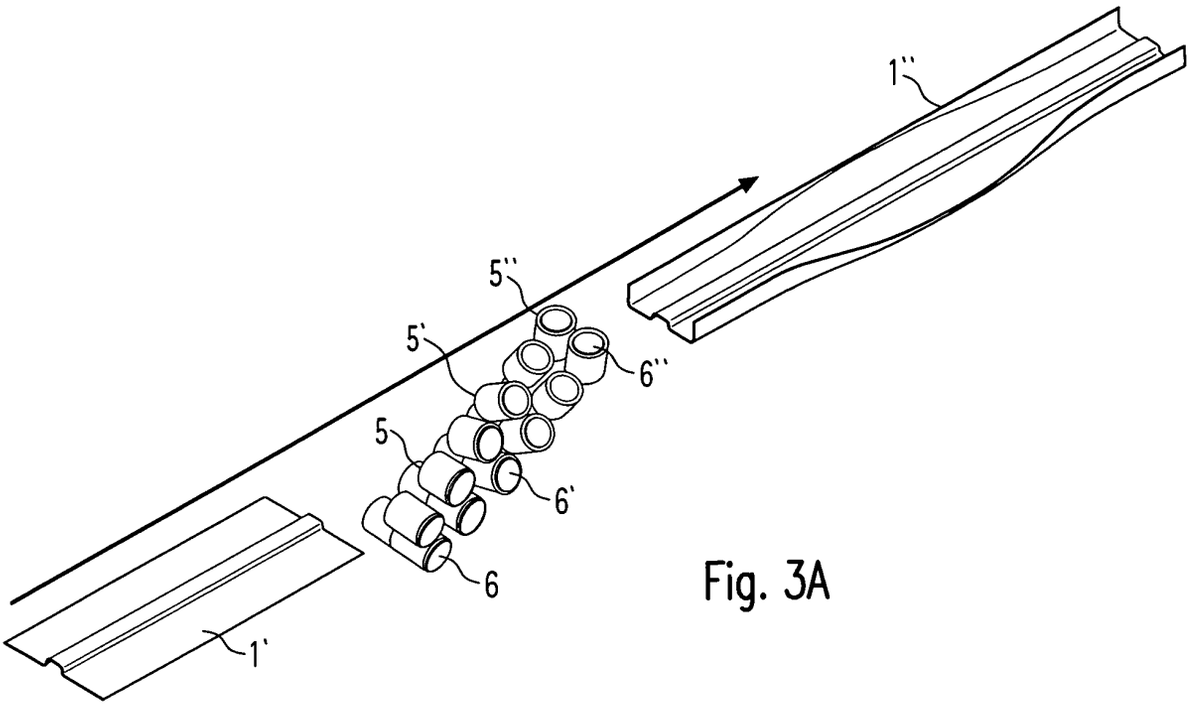

Fig. 3A

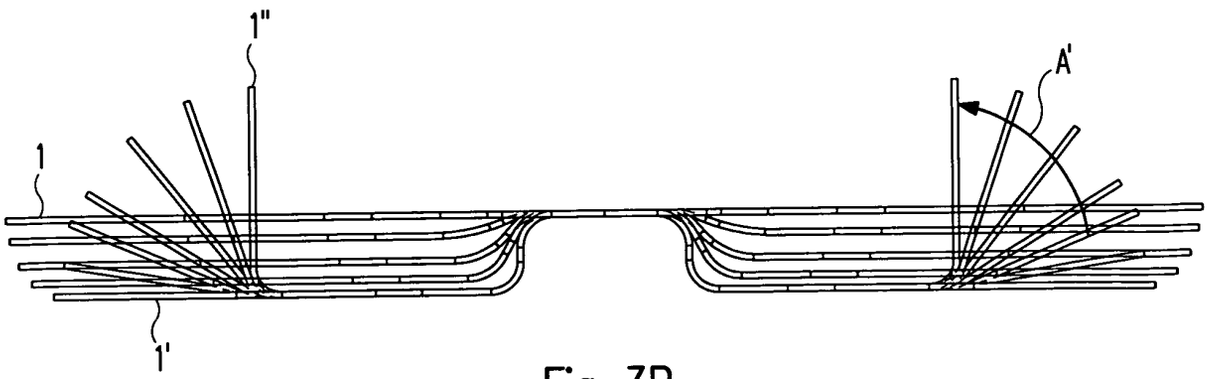

Fig. 3B

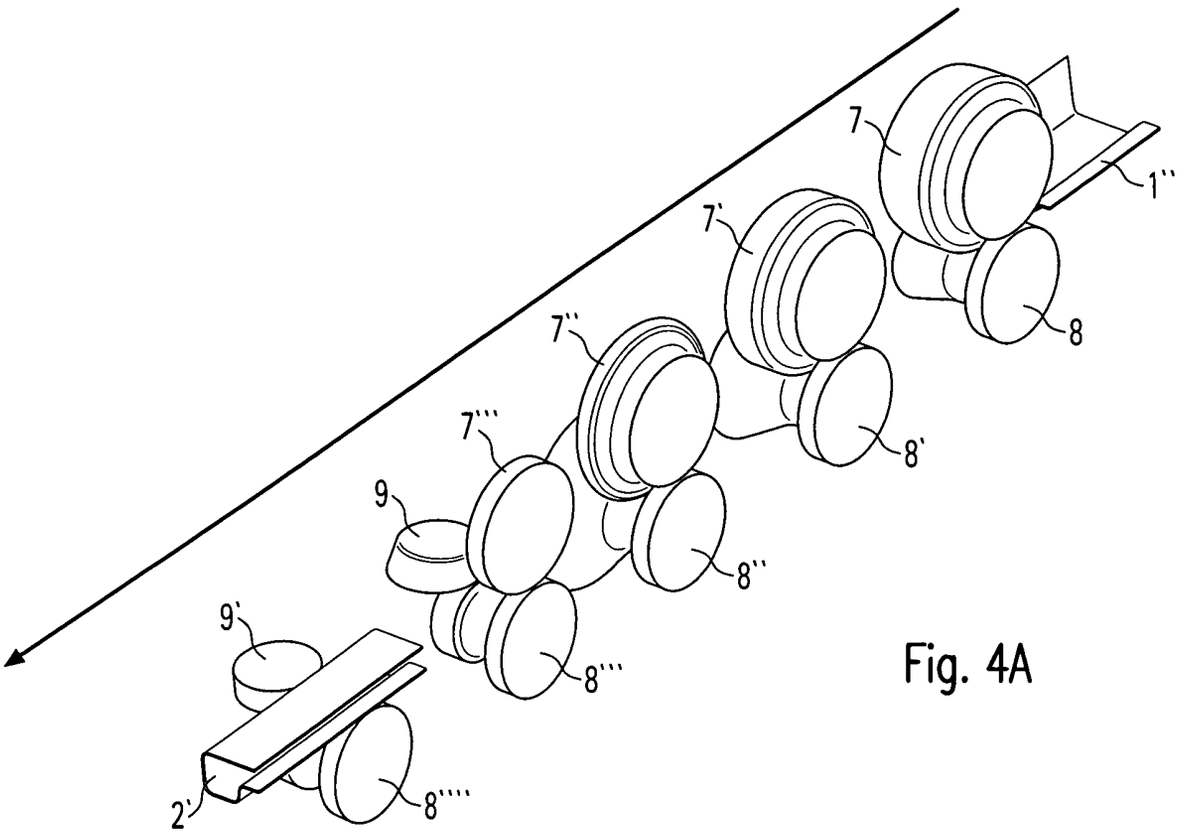

Fig. 4A

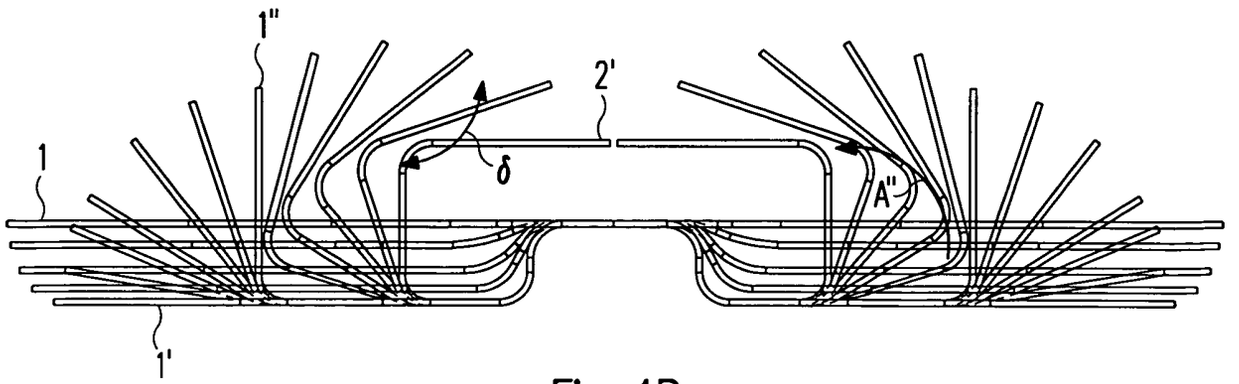

Fig. 4B

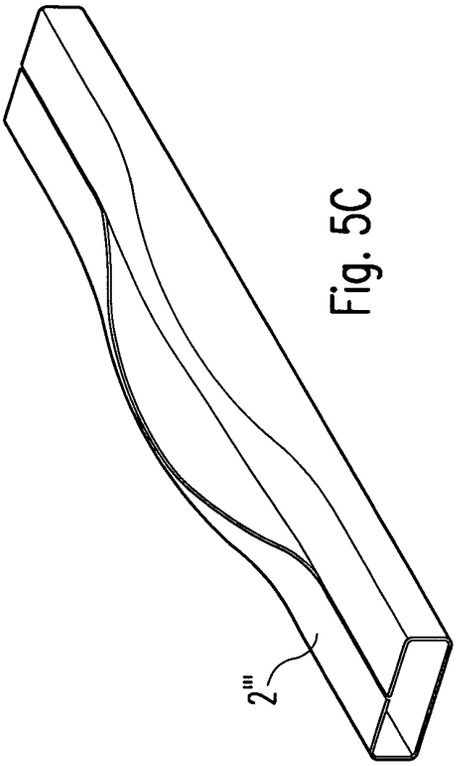

Fig. 5C

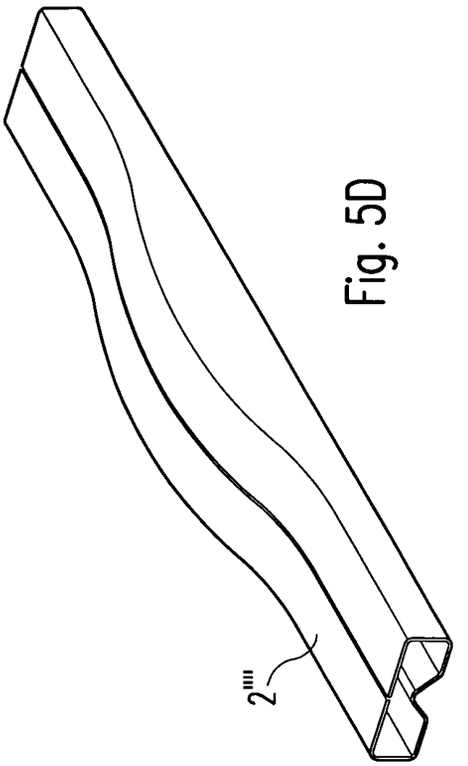

Fig. 5D

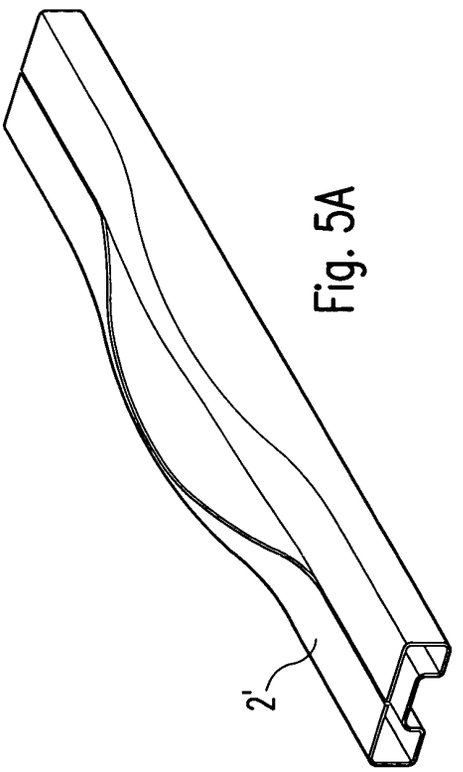

Fig. 5A

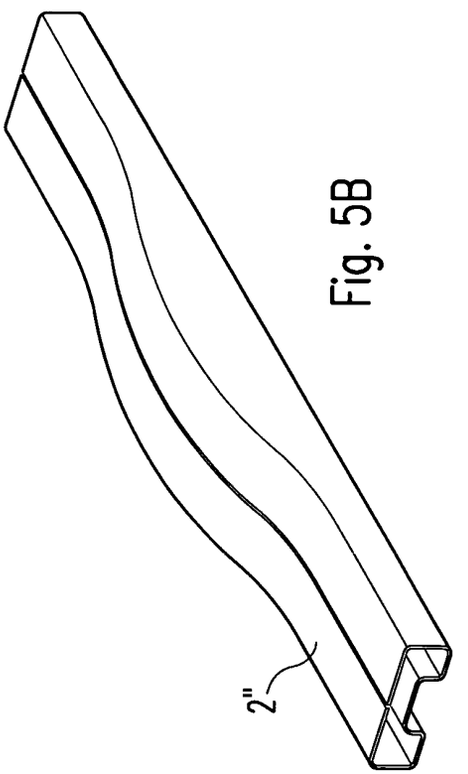

Fig. 5B

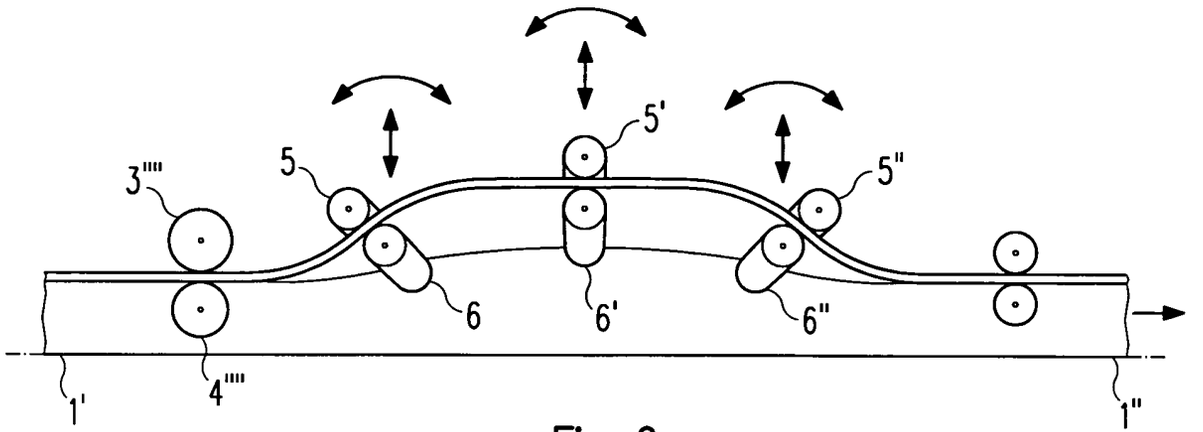

Fig. 6

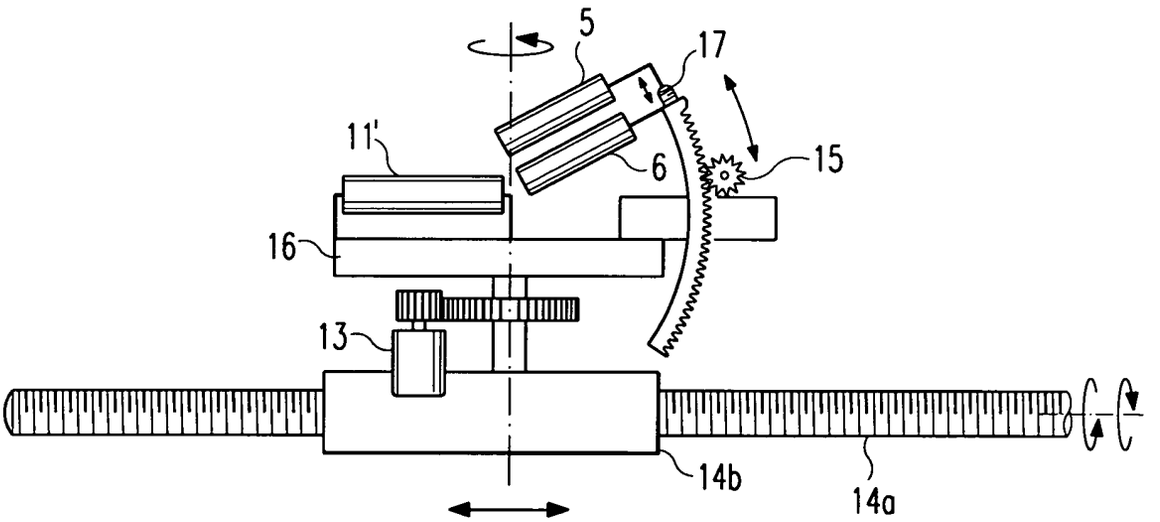

Fig. 7

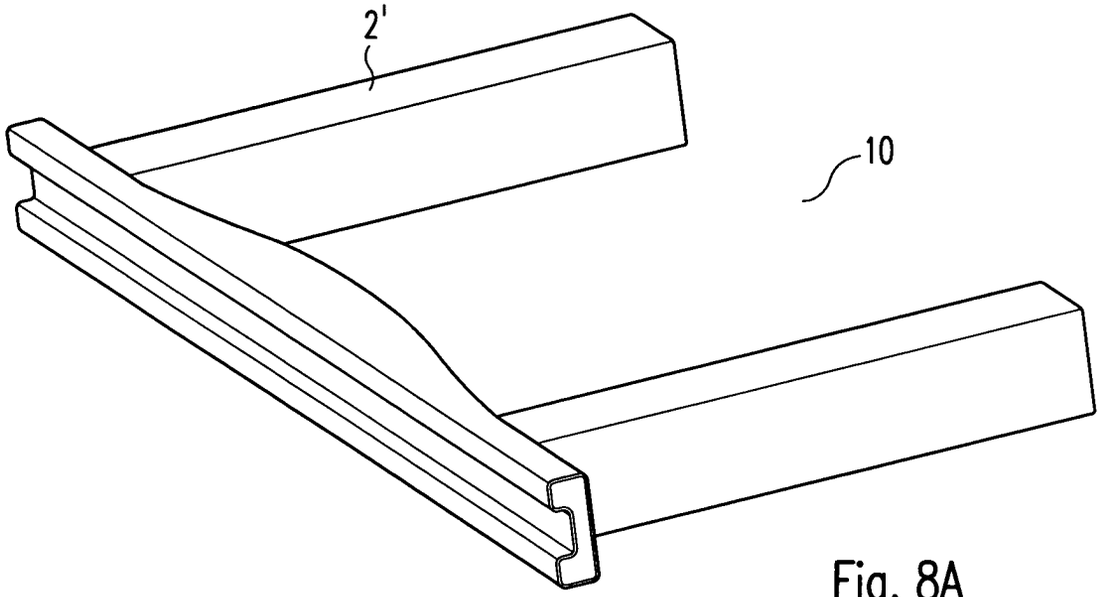

Fig. 8A

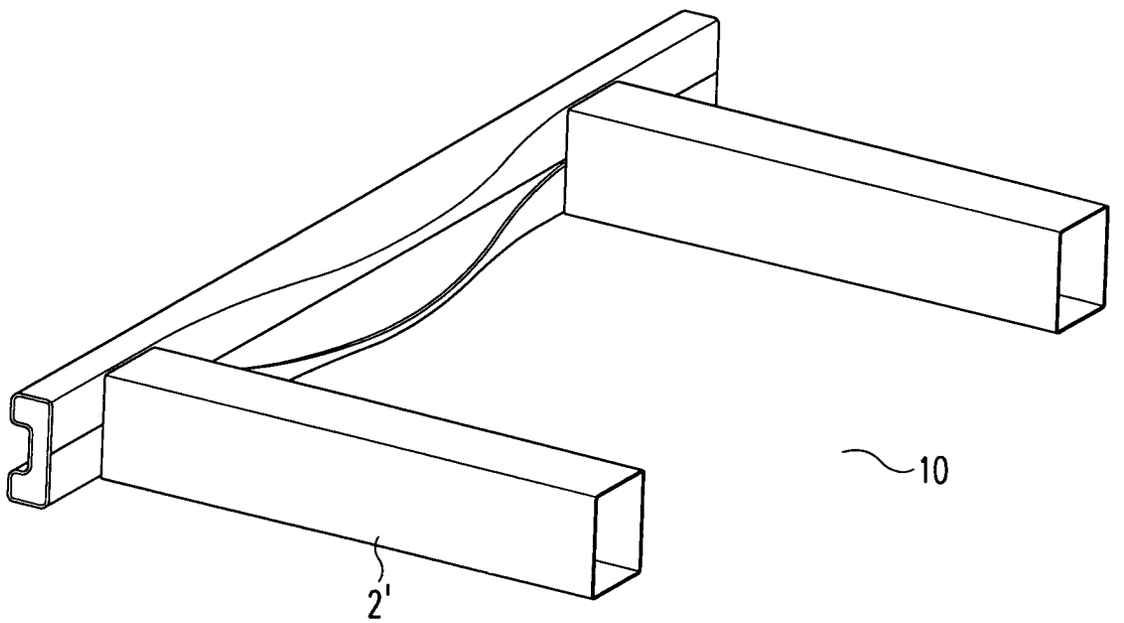

Fig. 8B

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 02 7867

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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X	PATENT ABSTRACTS OF JAPAN vol. 008, no. 124 (M-301), 9 June 1984 (1984-06-09) -& JP 59 027723 A (SHIRAKI KINZOKU KOGYO KK), 14 February 1984 (1984-02-14) * abstract *	1-29	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	14 May 2004	Vinci, V

CATEGORY OF CITED DOCUMENTS

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