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(54) METHOD FOR MANUFACTURING A DIAPHRAGM BELLOWS MEMBER

(57) A method for manufacturing a diaphragm bellows member (1) from a work (10) which is thin walled, axisymmetric and metal, the method comprising: a hydroforming step of applying a hydrostatic pressure (P) to the interior of the work (10) whilst a plurality of dies (20, 21, 22) surround the outside circumference of the work (10), the axial positions of the dies (20, 21, 22) being changed to allow the work (10) to contract axially as it expands radially under the hydrostatic pressure into spaces between adjacent dies (20, 21, 22), thereby forming corrugations (5) in the work (10); an expanding step, performed after the hydroforming step, of applying an outward axial force to the work (10) whilst changing the axial positions of the dies (20, 21, 22) to allow the work (10) to extend axially as the shape of the work (10) bends under the outward axial force; and a die removal step of removing the dies (20, 21, 22) between adjacent corrugations (5) whilst the outward axial force is applied to the work (10).

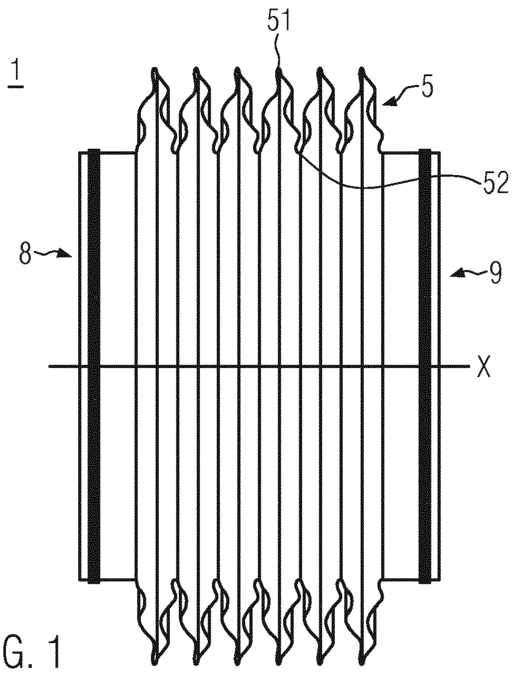

FIG. 1

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Description

[0001] The present invention refers to a method for manufacturing a diaphragm bellows, the method forming the diaphragm bellows member out of a thin-walled, metal, axisymmetric work.

[0002] Diaphragm bellows members are known and commonly used, for example, in flexible conduits that convey gas at a negative gauge pressure. A diaphragm bellows member has corrugations along its longitudinal axis that form alternating ridges and grooves. Furthermore, the corrugations have undulations so that in a portion between a groove and an adjacent ridge, the corrugations follow a curving profile with at least two points of inflection. The corrugations endow the diaphragm bellows member with flexibility so that it may be bent, extended and compressed. The wavy corrugation profile increases the resistance of the corrugations to buckling and collapse when subject to external pressure. Often the ridge and groove tips will have V-shaped profiles to reduce axial stiffness and reduce the axial length of each corrugation, thus reducing the radial pressure load on each corrugation, increasing overall flexibility of the diaphragm bellows member, and reducing the overall length of the diaphragm bellows member.

[0003] A known method of manufacturing such a diaphragm bellows member involves forming a plurality of annular diaphragms from flat sheet metal using a punch and press or the like, and then welding, alternately, the inner and outer circumferential edges of adjacent annular diaphragms in a series, thereby forming the diaphragm bellows member.

[0004] Another method of manufacturing such a bellows member involves successively applying a hydroforming process along a thin walled cylindrical metal tube, individually forming an intermediate corrugation each time. The series of intermediate corrugations are then compressed using dies at either end of the series, collectively forming them to produce the desired corrugation profile. Such a method is known from, for example, US 6 564 606 B2.

[0005] It is an object of the present invention to improve the efficiency of manufacturing a diaphragm bellows member.

[0006] This object is achieved with the method defined in independent claim 1. Such a method, being suitable for manufacturing a diaphragm bellows member from a work which is thin walled, axisymmetric and metal, comprises: a hydroforming step of applying a hydrostatic pressure to the interior of the work whilst a plurality of dies surround the outside circumference of the work, the axial positions of the dies being changed to allow the work to contract axially as it expands radially under the hydrostatic pressure into spaces between adjacent dies, thereby forming corrugations in the work; an expanding step, performed after the hydroforming step, of applying an outward axial force to the work whilst changing the axial positions of the dies to allow the work to extend axially as the shape of the work bends under the outward axial force; and a die removal step of removing the dies between adjacent corrugations whilst the outward axial force is applied to the work.

[0007] By these features a multiple corrugations may produced with an appropriate corrugation profile in a single forming process, thereby reducing production time and damage, such as work hardening, to the metal material of the diaphragm member. In particular, the expanding step allows the dies to be removed even when the dies and the corrugations overlap in a radial direction and radial movement of the dies would otherwise be obstructed. These benefits may be realized even if the corrugations formed only constitute an intermediate profile and further forming is required before corrugation profile is complete.

[0008] Furthermore, the forming surfaces of the dies have die undulations that intersect a radial plane along at least two different circumferential lines.

[0009] By this feature, the corrugations formed in the hydroforming step may be produced with a more suitable profile for use in a diaphragm bellows member. The requirement of further processing to refine the corrugation profile may also be reduced or eliminated.

[0010] Furthermore, during the hydroforming step, hydrostatic pressure may force the work to conform to die undulations so that, in a rest state, the corrugations formed in the hydroforming step have undulations that intersect the radial plane along at least two different circumferential lines.

[0011] By this feature, the corrugations formed in the hydroforming step may be produced with an even more suitable profile for use in a diaphragm bellows member. The requirement of further processing to refine the corrugation profile may also be reduced or eliminated.

[0012] Furthermore, the corrugations may undergo only elastic deformation in the period after the completion of the hydroforming step and before the completion of the die removing step.

[0013] By this feature damage such as work hardening may be suppressed, facilitating further forming processes, if necessary, and a need for heat treatments may be reduced or eliminated.

[0014] Furthermore, during the hydroforming step, opposing parallel portions of the forming surfaces of a pair of adjacent dies may be brought within a distance which is less than twice a wall thickness of the work.

[0015] By this feature the corrugations formed in the hydroforming step may be produced with a more suitable profile for use in a diaphragm bellows member. The requirement of further processing to refine the corrugation profile may also be reduced or eliminated.

[0016] Furthermore, the method may be carried out where, during the hydroforming step: a forming surface of a die has an outer surface portion that partially faces a radially inward direction, and the outer surface portion is shaped so that, when moving along the outer surface portion in a direction away from the bellows axis, a minimum distance to an opposing forming surface of an adjacent die increases.

[0017] By this feature the corrugations produced in the hydroforming step may be formed with a profile that facilitates further processing. In particular, the space within a corrugation ridge may increase when moving radially outward. Subsequent compression which increases curvature in the ridge and rotates the portions on either side toward each other might then more effectively close or contract a space within the corrugation.

[0018] Additionally, whether or not there is a subsequent forming process, the ridge may be formed with a low curvature whilst still inhibiting an increase in the axial length of the corrugation. Thus, stress concentrations around the ridge may be suppressed whilst still retaining a reduced radial pressure load on each corrugation, high overall flexibility of the diaphragm bellows member, and a reduced overall length of the diaphragm bellows member

[0019] Furthermore, a forming surface of a die may have an inner surface portion that partially faces a radially inward direction, and the inner surface portion may be shaped so that, when moving along the inner surface portion in a direction away from the bellows axis, a minimum distance to an opposite forming surface of the die increases.

[0020] By this feature the corrugations produced in the hydroforming step may be formed with a profile that facilitates further processing. In particular, the space within a corrugation groove may increase when moving radially outward. Subsequent compression which increases curvature in the ridge and rotates the portions on either side toward each other might then more effectively close or contract a space within the corrugation.

[0021] Additionally, whether or not there is a subsequent forming process, the groove may be formed with a low curvature whilst suppressing an increase in the axial length of the corrugation. Thus, stress concentrations around the ridge may be suppressed whilst still retaining a reduced radial pressure load on each corrugation, high overall flexibility of the diaphragm bellows member, and a reduced overall length of the diaphragm bellows member.

[0022] Also additionally, the axial size of the forming surface of the tip of the die may also be increased whilst suppressing an increase in the axial length of the corrugation. Thus, bearing stresses in the corresponding portion of the work during hydroforming may be reduced. Thus, the range of possible hydroforming process parameters, such as forming rate, fluid pressure, temperature, and work thickness, may be increased. Thus, the process may be made faster, more economical and more flexible, and the product produced may also be improved.

[0023] Furthermore, the method may comprise a compression forming step, performed after the die removal step, of applying an inward axial force to a series of adjacent corrugations from which dies have been removed, thereby forming the series of adjacent corrugations so that they become compressed corrugations.

[0024] By this feature the corrugations formed in the manufacturing process may be produced with a more suitable profile for use in a diaphragm bellows member.

[0025] Furthermore, the inward axial force may be applied via a compression die abutting an axially outward facing surface of an end corrugation at one end of the series of adjacent corrugations, and via an opposing compression die abutting an opposite axially facing surface of another end corrugation at an opposite end of the series of corrugations, and a forming surface of the compression die may mate with an opposing forming surface of the opposing compression die.

[0026] By this feature consistent forming throughout the series of corrugations may be attained in the compression step, and an axial length of diaphragm bellows member may be reduced.

[0027] Furthermore, during the hydroforming step, the compression dies may be used as dies.

[0028] By this feature utilization of the compression dies may be increased, whilst the cost of transitioning from the hydroforming step to the compression forming step may be reduced.

[0029] Furthermore, the axial length in a rest state of the series of adjacent corrugations, after the hydroforming step, may be more than 150% of the axial length in a rest state of series of adjacent corrugations after the compression forming step.

[0030] By this feature, the corrugations with a suitable profile for use in a diaphragm bellows member may be more efficiently produced whilst suppressing damage to the metal and a need for heat treatment

[0031] Furthermore, the axial length between two dies at the start of plastic deformation in the hydroforming step may be more than 200% of the minimum axial length between the two dies during the hydroforming step.

[0032] By this feature, the corrugations formed in the hydroforming step may be produced with a more suitable profile for use in a diaphragm bellows member. The requirement of further processing to refine the corrugation profile may also be reduced or eliminated. Damage such as work hardening may also be suppressed, facilitating further forming processes, if necessary, and a need for heat treatments may be reduced or eliminated.

[0033] In the following, the invention will be explained in detail using the following drawings.

Fig. 1 is a sectional view schematically showing half of a diaphragm bellows member manufactured according to an embodiment of the invention.

Fig. 2 is a sectional view schematically showing a portion of the dies and work at a start of a hydroforming step according to an embodiment of the invention.

Fig. 3 is a sectional view schematically showing a portion of the dies and work during a hydroforming step according to an embodiment of the invention.

Fig. 4 is a sectional view schematically showing a portion of the dies and work at the end of a hydroforming step according to an embodiment of the invention.

Fig. 5 is a sectional view schematically showing a portion of the dies and work at the end of an extending step according to an embodiment of the invention.

Fig. 6 is a sectional view schematically showing the corrugation profile produced by a hydroforming step according to an embodiment of the invention.

Fig. 7 is a sectional view schematically showing a portion of the compression dies and work at the end of a compression forming step according to an embodiment of the invention.

Fig. 8 is a sectional view schematically showing the corrugation profile produced by a compression forming step according to an embodiment of the invention.

Fig. 9 is a photograph showing a cross section of the corrugations in a diaphragm bellows member produced according to an embodiment of the invention.

Fig. 10 is an enlargement of the photograph in Fig. 9, showing a detailed view of the left hand corrugations ridges.

Fig. 11 is an enlargement of the photograph in Fig. 9, showing a detailed view of the right hand corrugations grooves.

[0034] A first embodiment of the invention will now be described with reference to Figs 1 to 6.

[0035] A diaphragm bellows member 1 shown in Fig. 1 has a plurality of circumferential grooves 51 and ridges 52 that are arranged alternately in the axial direction of the bellows member sites such that they form corrugations 5. Between each groove 52 and ridge 51, the corrugations 5 have undulations so that a W shaped profile is formed.

[0036] At either end of the corrugated portion of the diaphragm bellows member 1 there are cylindrical end portions 8, 9 by which the diaphragm bellows member 1 may be rigidly attached to adjacent components.

[0037] Figs. 2-4 show a schematic depiction of a hydroforming step in the manufacture of the diaphragm bellows member 1. The hydrostatic forming step forms a work 10 which starts as a thin-walled, metal cylindrical tube. The metal is typically an austenitic stainless steel but is not specifically restricted. Any alloy with sufficient formability may be used. Typical wall thicknesses of the work 10 are less than 0.5 mm. For many applications, a thickness between 0.15 mm and 0.25 mm is preferable. The work 10 need not be precisely cylindrical but should be substantially axisymmetric in the region that is to be formed.

[0038] A plurality of dies 20, 21, 22, each of which surrounds a circumference of the work 10, are arranged at regular intervals in the axial direction along the work 10. The end dies 21, 22 each have a forming surface 24, 25 that faces toward the other 25, 24. Each die 20 in between each has a forming surface 24 and an opposite forming surface 25 facing opposite axial directions. Each die 20 in each adjacent pair of dies 20, 20 has a forming surface 24, 25 facing an opposing forming surface 25, 24 on the other die 20 of the adjacent pair of dies 20, 20.

[0039] In the hydroforming step, the work 10 is filled with pressurized fluid. The internal pressure pushes the work 10 to expand radially in the spaces between each pair of adjacent dies 20, 21, 22, as shown in Figs 3 and 4. This radial expansion causes the work 10 to contract axially, and so the spacing between the dies 20, 21, 22 is reduced accordingly, as shown in Figs 2 to 4. The hydrostatic pressure not only causes radial expansion, but also axial deformation as the work 10 expands to conform to the undulating forming surfaces 24, 25 of the dies 20, 21, 22.

[0040] Eventually, adjacent dies 20, 21, 22 or their forming surfaces 24, 25 may be brought into abutment, as shown in Fig 4. The axial contraction may also cease when a portion of the work is pinched between the opposing forming surfaces 24, 25 of adjacent dies 20m, 21, 22, or at an earlier desired contraction state where there is no contact preventing further contraction.

[0041] In this way the work 10 can be caused to plastically deform so as to conform to the forming surfaces 24, 25 of the dies 20, 21, 22, and a plurality of corrugations 5 suitable for a diaphragm bellows member 1 may be collectively formed in a single manufacturing process.

[0042] Subsequent release of the hydrostatic pressure allows some elastic recovery of the work 10 so that it no longer conforms to the forming surfaces 24, 25 of the dies 20, 21, 21. However, the undulations of the dies 20, 21, 22 may still overlap with the undulations of the work 10 in a radial direction, preventing removal of the dies 20. In order to traverse this restriction, the spacing between the dies 20, 21, 22 is then increased and an outward axial force F_x is applied to the ends of the work 10 in an expanding step, causing the work 10 to deform and bend away from the forming surfaces 24, 25 of the dies 20, 21, 22, as shown in Fig 5. As a result, the dies 20 may then be removed from the work 10 in a die removing step.

[0043] The expanding step may be controlled so as to prevent further plastic deformation of the work 10, and thus avoiding permanent increase in the length of the work 10. However, the expanding step may be controlled so as to cause plastic deformation of the work 10. The geometry of the corrugation profile may be contrived so as to create bending moments and concentrate stresses in favorable locations, in order to generate a corrugation profile suitable for a diaphragm bellows member 1. It may be preferable to exploit the plastic deformation thus generated and extend the work 10 more than necessary for removal of the dies in order to create a corrugation profile preferable for a diaphragm bellows member 1 for certain applications.

[0044] The diaphragm bellows member 1 thus produced may be suitable for use without further processing. However, as noted above, reducing an axial length of each corrugation 5 can reduce the radial pressure load on each corrugation 5, increase overall flexibility of the diaphragm bellows member 1, and reduce the overall length of the diaphragm bellows member 1. Accordingly, in a preferred embodiment, the work 10 may then be subject to a second forming process which is a compression forming step that causes further plastic deformation of the work 10 so that the axial length of each corrugation 5 is reduced, as shown in Figs 6 to 8. In the compression forming step a compression die 23 is fitted against an axially outward facing surface of an end corrugation 5 and an opposing compression die 24 is fitted against an axially opposite facing surface of another end corrugation 5 that is at an opposite end 56. The compression dies 23, 24 and then brought together to apply axially inward force F_c to the corrugations 5, compressing and plastically deforming them further, as shown in Fig 7. Upon removal of the axial inward force F_c there is some elastic recovery of the work 10 but there is retained at least a reduction in the axial length and compressed corrugations 6 may be produced, as shown in Fig 8.

[0045] It should be noted that in order to facilitate forming of the work 10 throughout the embodiments, temperature and strain rate may be controlled to prevent damage and degradation in formability. In particular, heat treatments may be applied to ameliorate work hardening.

[0046] As shown in Fig 7, the work 10 may be compressed in the compression forming step so that a series 50 of corrugations 5 are brought in contact with each other so as to form a body that is effectively solid in compression. This may minimize an axial length of the diaphragm bellows member 1 but is not, however, strictly necessary. It may be preferable merely to apply an axial force that generates a bending moment in the corrugations 5 that cause plastic deformation without bringing the corrugations 5 into contact with each other.

[0047] In case the corrugations 5 are brought in contact with each other in the compression forming step, it is preferable that the forming surface 26 of the compression die 23 mates with the opposing forming surface 27 of the opposing compression die 24 so that each corrugation 5 experiences similar strains and plastic deformation.

[0048] In this case the end dies 21, 22 used in the hydroforming step may also be used as compression dies 23, 24. This may cause a slight difference in the corrugation profile of the end corrugations 5 formed in the hydroforming step, but can enable transition to a compression step without having to replace the end dies 21, 22.

[0049] In case the corrugations 5 are not brought in contact with each other in the compression forming step, it is preferable that the axial force F_c is applied as a point load (or a circumferential line load), so that each corrugation 5 experiences similar bending moments, and therefore similar strains and plastic deformation. For example, it may be preferable to apply the inward axial force F_c via the cylindrical end portions 8, 9 of the diaphragm bellows member 1.

[0050] Although figures 1 to 6 depict corrugation profiles produced by a hydroforming step where a space between opposite sides of a groove 52 gets smaller the closer it gets to the tip of the groove 52, it may in fact be preferable that this space sometimes increases when moving closer to the tip of a groove 52. In particular, because of the bending moments created at the tip of the groove 52 and the high bearing stress concentration that is generated by the tip of the die during the hydroforming step, it may be preferable to increase the size of the space in the tip of the groove 52 relative to the size of the space further up in the groove 52, thereby reducing the curvature so that bending moment concentrations can be suppressed and increasing the surface area that can bearing stress concentrations can be suppressed.

[0051] Similarly, it may be preferable that the size of the space in the tip of the ridge 51 is greater than that further down from the ridge 51.

[0052] This may be particularly advantageous if a subsequent compression forming step is applied, as this geometry may enable opposite sides of a groove 52 or ridge 51 to be brought closer to parallel or even in contact with each other when the tip of the ridge 51 or groove 52 is compressed in the subsequent compression forming step. In fact, these features may enable portions of the compressed corrugations 6 on opposite sides of a groove 52 or ridge 51, in a portion up or down from the groove 52 or ridge 51, respectively, to be brought into contact with each other with a significant residual contact force that is sustained even when the diaphragm bellows member 1 is at rest. A diaphragm bellows member 1 in this configuration may attain improved durability because, as the diaphragm bellows member 1 is compressed, extended, bent, or sheared, compression and extension forces acting on the corrugations 5 may be absorbed by this contact rather than through the tip of the ridge 51 or groove 52. Specifically, a compression force may cause an increase in the contact pressure and the area of contact, and an extension force may cause a decrease in the contact pressure and the area of contact, whilst the stress in the tip of the ridge 51 or groove 52 is unchanged. Even though the residual contact force causes residual stresses in the tip of the ridge 51 or groove 52, fluctuations in the axial load may thus be absorbed without changing the stress at the tip of the ridge 51 or groove 52. Thus, the fluctuation of stresses in the ridge 51 or groove 52, where the stresses might otherwise be concentrated, may be suppressed. Thus, damage resulting from fluctuating stresses (i.e. metal fatigue) may be suppressed and a service life may thereby be improved.

[0053] Thus, an embodiment of the invention can produce a metal diaphragm bellows member 1 with formed cylindrical compressed corrugations 6, each corrugation having a profile with at least two points of inflection between the tip of the groove 52 and the tip of an adjacent ridge 51, and where, in a rest state, a portion of a corrugation 6 on one side of the tip of a groove 52 is held in contact with another portion of a corrugation 6 on the other side of the tip of the groove 52 by a force sustained by residual stresses in the groove 52, and/or, a portion of a corrugation 6 on one side of the tip of a ridge 51 is held in contact with another portion of a corrugation 6 on the other side of the tip of the ridge 51 by a force sustained by residual stresses in the ridge 51.

[0054] Figs 9 to 11 show a photograph of a cross section of the compressed corrugations 6 in a diaphragm bellows member 1 produced according to an embodiment of the invention. The detail enlargement in Fig. 10, in particular, shows the contact that can be created between the walls of the compressed corrugations 6 on either side of a ridge.

[0055] Furthermore, a curvature can be increased at the tip of the ridge 51 and/or groove 52 while a space away from the tip of the ridge 51 and/or groove 52 is reduced. Bending moment concentrations may thereby be further suppressed whilst still suppressing an increase in the axial length of the corrugation 6. This may be enhanced by pinching a portion of the corrugations 5 between adjacent opposing forming surfaces during the hydroforming step. Although this can only be carried out near the ridge 51, a reduction in the stress concentrations whilst suppressing an increase in the axial length may still be attained.

Claims

1. A method for manufacturing a diaphragm bellows member (1) from a work (10) which is thin walled, axisymmetric and metal, the method being **characterized by** comprising:

   a hydroforming step of applying a hydrostatic pressure (P) to the interior of the work (10) whilst a plurality of dies (20, 21, 22) surround the outside circumference of the work (10), the axial positions of the dies being changed to allow the work (10) to contract axially as it expands radially under the hydrostatic pressure into spaces between adjacent dies, thereby forming corrugations (5) in the work (10);
   an expanding step, performed after the hydroforming step, of applying an outward axial force (F_x) to the work (10) whilst changing the axial positions of the dies to allow the work (10) to extend axially as the shape of the work (10) bends under the outward axial force; and
   a die removal step of removing the dies (20) between adjacent corrugations (5) whilst the outward axial force (F_x) is applied to the work (10).

2. A method according to claim 1, wherein:

   forming surfaces (24, 25) of the dies (20, 21, 22) have die undulations that intersect a radial plane along at least two different circumferential lines.

3. A method according to at least claim 2, where, during the hydroforming step:

   hydrostatic pressure forces the work (10) is to conform to die undulations so that, in a rest state, the corrugations (5) formed in the hydroforming step have undulations that intersect the radial plane along at least two different circumferential lines.

4. A method according to at least one of claims 1 to 3, wherein the corrugations (5) undergo only elastic deformation in the period after the completion of the hydroforming step and before the completion of the die removing step.

5. A method according to at least one of claims 1 to 4, where, during the hydroforming step:

   opposing parallel portions of the forming surfaces (24, 25) of a pair of adjacent dies (20, 20) are brought within a distance which is less than twice a wall thickness of the work (10).

6. A method according to at least one of claims 1 to 5, wherein, during the hydroforming step:

   a forming surface (24, 25) of a die (20) has an outer surface portion that partially faces a radially inward direction, and
   the outer surface portion is shaped so that, when moving along the outer surface portion in a direction away from the bellows axis (X), a minimum distance to an opposing forming surface (25, 24) of an adjacent die (20) increases.

7. A method according to at least one of claims 1 to 6, wherein:

   a forming surface of a die (24, 25) has an inner surface portion that partially faces a radially inward direction, and
   the inner surface portion is shaped so that, when moving along the inner surface portion in a direction away from the bellows axis, a minimum distance to an opposite forming surface (25, 24) of the die (20) increases.

8. A method according to at least one of claims 1 to 7, wherein the method further comprises:

a compression forming step, performed after the die removal step, of applying an inward axial force (F_c) to a series (50) of adjacent corrugations (5) from which dies have been removed, thereby forming the series (50) of adjacent corrugations (5) so that they become compressed corrugations (6).

9. A method according to claim 8, wherein:

the inward axial force (F_c) is applied via a compression die (23) abutting an axially outward facing surface of an end corrugation at one end (55) of the series (50) of adjacent corrugations (5), and via an opposing compression die (24) abutting an opposite axially facing surface of another end corrugation at an opposite end (56) of the series (50) of corrugations (5), and
a forming surface (26) of the compression die (23) can mate with an opposing forming surface (27) of the opposing compression die (24).

10. A method according to claim 8 or 9, where, during the hydroforming step:

the compression dies (23, 24) are used as dies (21, 22) in the hydroforming step.

11. A method according to at least one of claims 8 to 10, wherein the axial length in a rest state of the series of adjacent corrugations (50), after the hydroforming step, is more than 150% of the axial length in a rest state of series of adjacent corrugations (60) after the compression forming step.

12. A method according to at least one of claims 1 to 11, wherein the axial length between two dies (20, 20) at the start of plastic deformation in the hydroforming step is more than 150% of the minimum axial length between the two dies (20. 20) during the hydroforming step.

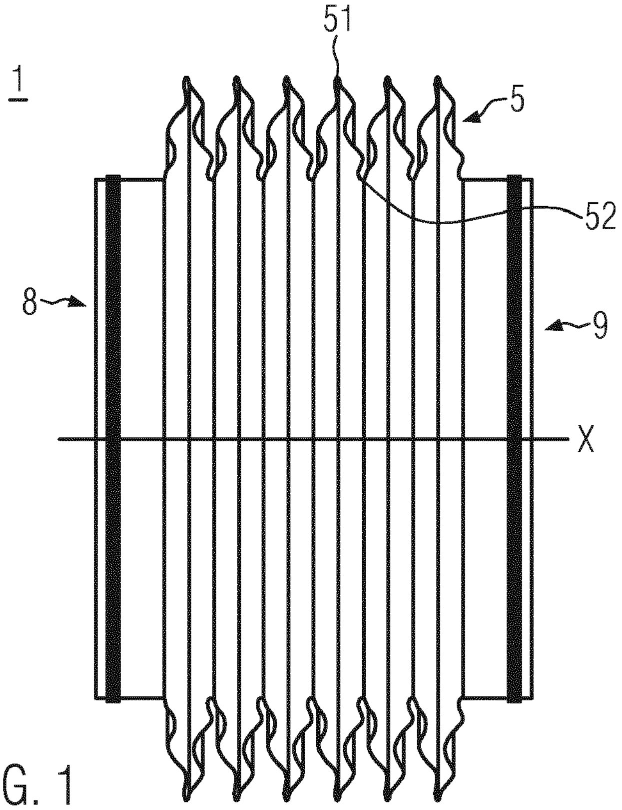

FIG. 1

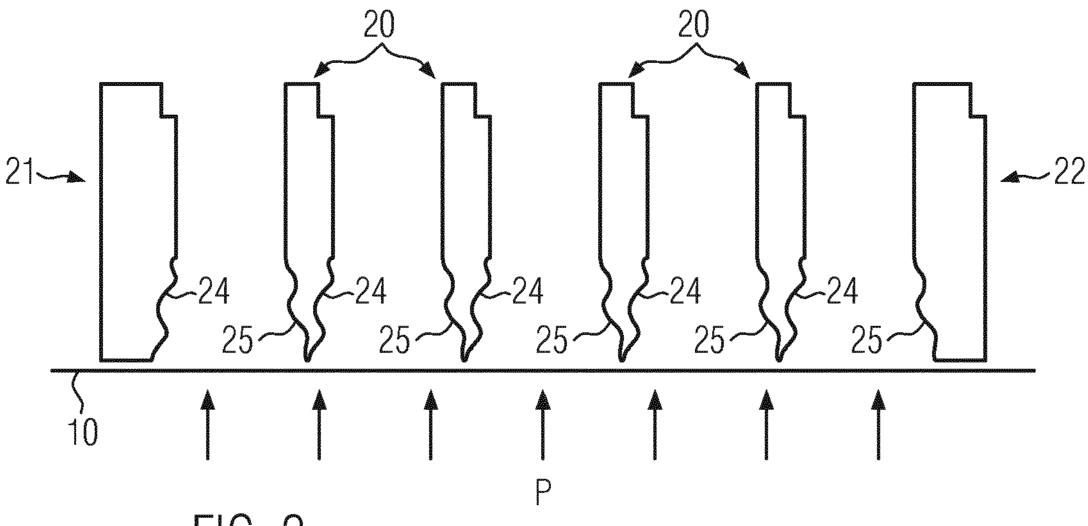

FIG. 2

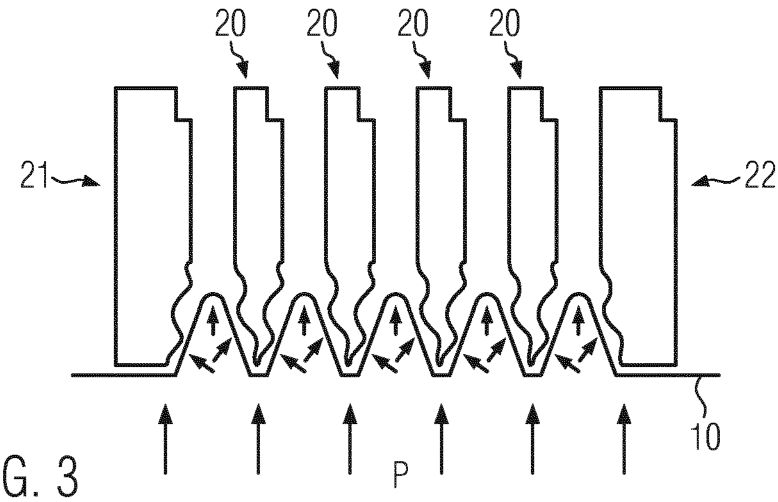

FIG. 3

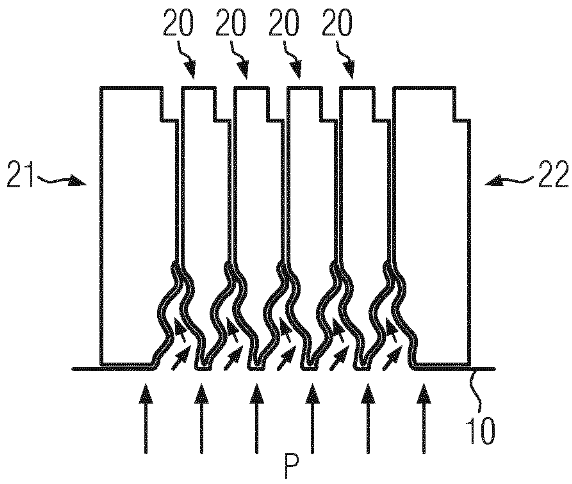

FIG. 4

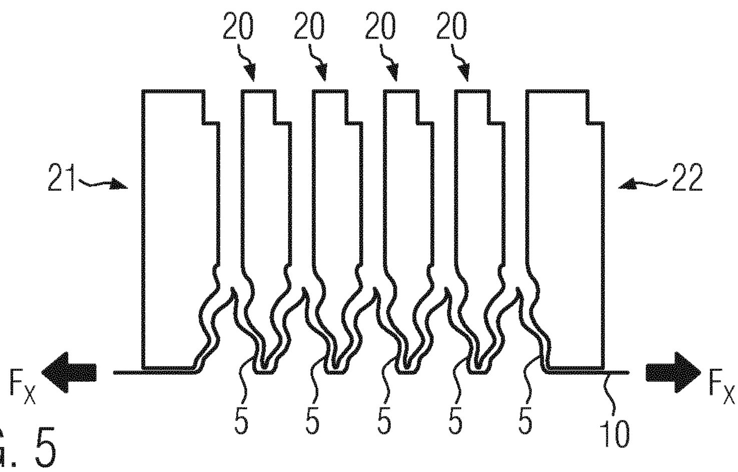

FIG. 5

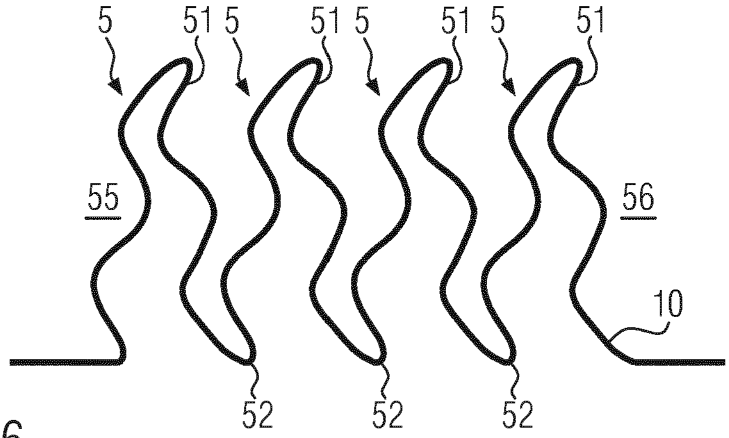

FIG. 6

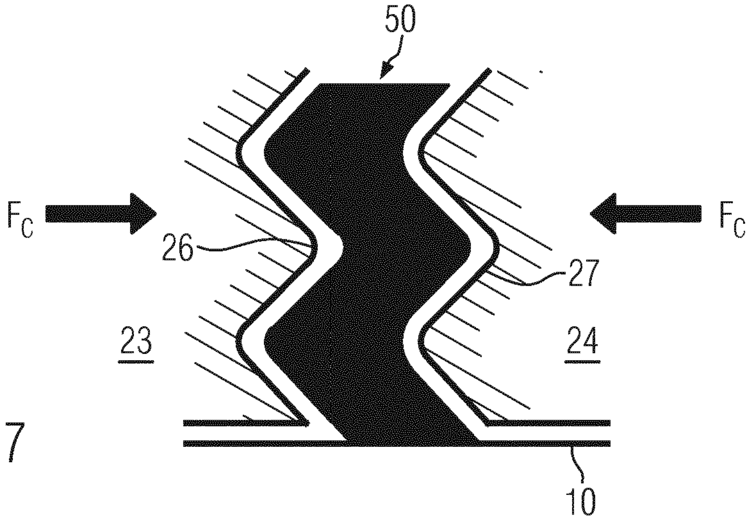

FIG. 7

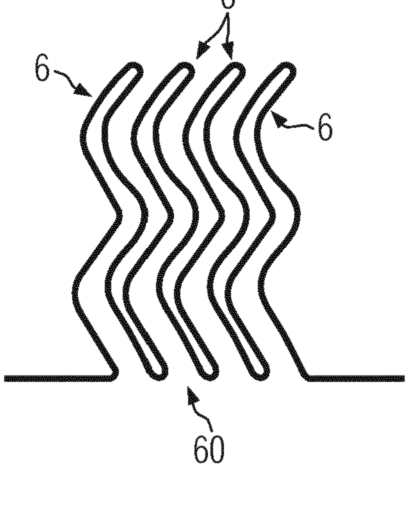

FIG. 8

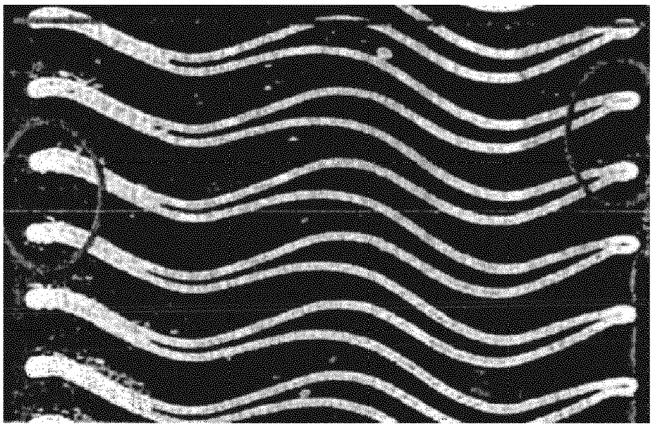

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FIG. 9

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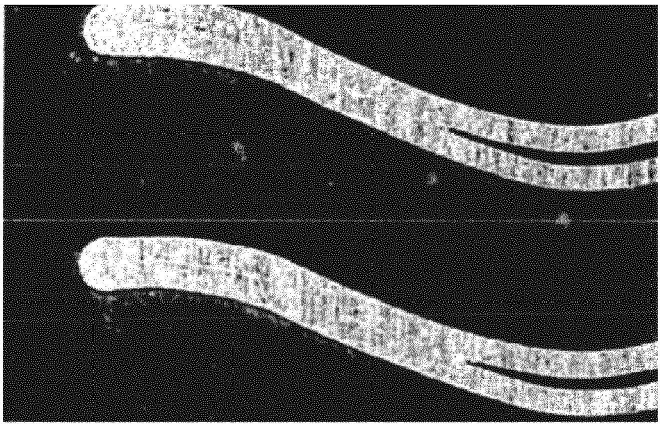

FIG. 10

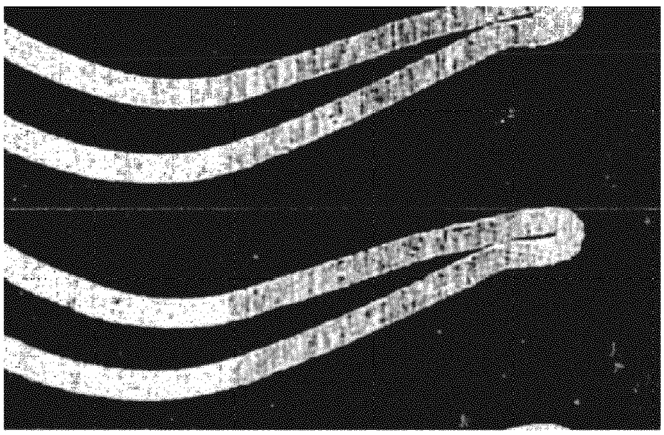

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FIG. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 16 20 7555

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A,D	US 2001/052253 A1 (OKADA HIDEKI [JP] ET AL) 20 December 2001 (2001-12-20) * the whole document * -----	1	INV. B21D15/10 B21D26/033
A	EP 1 325 784 A1 (NHK SPRING CO LTD [JP]) 9 July 2003 (2003-07-09) * paragraph [0017] - paragraph [0020]; figures * -----	1	
A	US 4 364 252 A (KOIZUMI CHIE) 21 December 1982 (1982-12-21) * column 2, line 41 - line 62; figures 4a-4c * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)

B21D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	29 June 2017	Pieracci, Andrea

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29-06-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2001052253 A1	20-12-2001	DE 60106812 D1	09-12-2004
		DE 60106812 T2	27-10-2005
		DE 60125070 T2	05-07-2007
		EP 1166912 A2	02-01-2002
		EP 1442805 A1	04-08-2004
		US 2001052253 A1	20-12-2001
EP 1325784 A1	09-07-2003	DE 60300026 D1	07-10-2004
		DE 60300026 T2	08-09-2005
		EP 1325784 A1	09-07-2003
		JP 4057297 B2	05-03-2008
		JP 2003202077 A	18-07-2003
		US 2003126732 A1	10-07-2003
US 4364252 A	21-12-1982	JP H0152095 B2	07-11-1989
		JP S56144830 A	11-11-1981
		US 4364252 A	21-12-1982

EPO FORM P0459

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Patent documents cited in the description

- US 6564606 B2 **[0004]**