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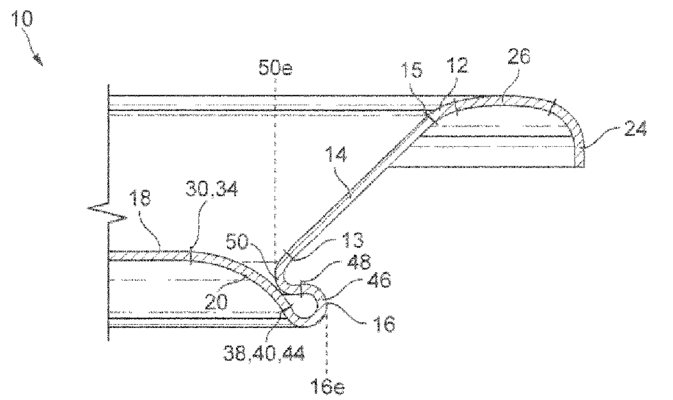

FIG. 4A

(57) Abstract: There is disclosed herein a can end (10) for a can for pressurized contents, the can end being configured to be joined by a peripheral annular joining portion (24,26) to one axial end of a can body of the can and having an outer side arranged to face outwardly from the can and an inner side arranged to face inwardly into the can, the can end comprising: a central panel (18); a panel wall (20) annularly surrounding the central panel and extending axially inwardly and radially outwardly from the central panel; an annular chuck wall structure (12, 14, 50) extending radially- and axially-inwardly from the joining portion; and an annular bead (16) which is connected between a radially outer edge (38) of the panel wall and a radially inner edge (50e) of the chuck wall structure and which is concave with respect to the outer side of the can end and extends at least partially radially outwardly with respect to the radially inner edge of the chuck wall structure, wherein wall portions adjacent inner and outer ends of the concave annular bead (16) form a bead mouth (m) that is open towards the outer side of the can end.

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CAN END

FIELD OF THE INVENTION

[0001] This invention relates to metal packaging and more particularly to a light weight can end, a method and apparatus for its manufacture, and a can having the can end. The invention is particularly concerned with beverage cans for carbonated drinks, and the provision of can ends therefor.

BACKGROUND TO THE INVENTION

[0002] Any discussion of the prior art throughout the specification should in no way be considered as an admission that such prior art is widely known or forms part of common general knowledge in the field.

[0003] Lightweight beverage can ends having an inclined chuck wall have become commercially popular. The first of such ends is disclosed in WO96/37414 and is sold under the tradename SUPEREND. This can end comprises a peripheral cover hook, a chuck wall dependent from the interior of the cover hook, an outwardly concave reinforcing bead extending radially inwards from the chuck wall, and a central panel supported by an inner portion of the reinforcing bead, characterised in that the chuck wall is inclined to an axis perpendicular to the exterior of the central panel at an angle between 20 degrees and 60 degrees. WO96/37414 shows a conventional annular reinforcing bead between the chuck wall and that centre panel.

[0004] The SUPEREND end as disclosed in WO96/37414 provided an improved strength to metal volume ratio in comparison to earlier can ends at least in part because the angle of the chuck wall allowed the central panel to be of a smaller diameter than earlier can ends, such that, when the can end was seamed onto a can and pressurised, it transmitted a lower force via the reinforcing bead to the chuck wall. Also, the angle of the chuck wall was suited to transmit the forces generated by pressurisation to the seam with little distortion.

[0005] However when this can end was submitted to excess or localised pressure, such as may result from an impact if the can was dropped, the chuck wall would flip outwards, creating a pointed pucker known as a “peak”, wherein the metal was prone

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to fracture and allow the contents of the can to leak. Such a failure became known as “peak and leak”.

[0006] WO 2006/050465 and US20100044383, each of which is assigned to the present assignee, describe control features to prevent the formation of such peaks. However, the benefit of such control features is partly offset by a general reduction in the pressure at which the end would permanently distort.

[0007] The technical advances of the SUPEREND can end provoked competing can end development, such as that described in United States Patent Numbers 7,819,275 and 6,702,142. Each of these can ends has a reinforcing bead having a rounded bottom and sidewalls that are either vertical or open outwardly.

[0008] The can end of WO 96/37414 is conventionally formed in a single press operation. The forming is carried out simply by axially moving several concentric tools, some of which are resiliently loaded by pistons or springs. Subsequently, further curling, scoring, embossing, lettering and tab attachment operations are typically carried out.

[0009] WO 2005/113351 describes a can end comprising a centre panel, a circumferential chuck wall and a transition wall, wherein the transition wall comprises a folded portion. Several methods are described whereby such a fold might be manufactured, including either a second forming operation or a squeezing operation as shown in figs 49-52 or 53-57 of WO 2005/113351, wherein the metal is collapsed in an uncontrolled “free-form” manner. The end disclosed in WO 2005/113351 has not been a commercial success.

[0010] In particular, the can ends of WO 2005/113351, in the main, require tightly compressed folds to be formed, with the overlapping portions of the fold pressed into contact along their facing surfaces. Not only is it likely that such a tightly-squeezed fold will damage the integrity of any coatings on the metal of the can end, but also the machinery needed to form the folds has to be of a significantly higher capacity than is typically available with existing reform presses, meaning that the can ends of WO 2005/113351 cannot in practice be made using existing manufacturing plant.

[0011] Another example in WO 2005/113351 is shown in Figure 11. Although the annular fold 54 in this example is not pressed fully flat, it will be appreciated that the

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fold still provides a neck throughout which the opposed sides of the fold are in contact. At the same time, the inner portion of the enclosed loop formed in the fold 54 faces axially inwardly and radially inwardly into the neck where the sides of the fold are in contact. Additionally, it will be appreciated that the multiple forming operations required to produce such an end will result in damage to coatings on, and create excessive strain in, the surface of the metal.

[0012] Strength, light weight, and diminished peak and leak phenomenon have been longstanding goals of can end engineering.

[0013] Connected with the strength of a can end is the resistance of the can end to outward deflection of the central panel when the can is internally pressurized. The central panel, as well as any opening tab formed on the outer surface of the panel, is typically recessed relative to the plane of the outer edge of the seam which joins the can end to the can. As the pressure differential between the inside and the outside of the can increases (with the can having a higher internal pressure than the external pressure), as may occur as a result of processing operations or changing environmental conditions to which the can is subjected, the central panel tends to dome and bulge outwardly. This will tend to push the central panel and any opening tab thereon outwardly relative to the seam, and may cause the opening tab to become exposed beyond the plane of the seam. In this condition, the opening tab is prone to snagging, which may interfere with further processing and packaging, and may lead to unintentional opening of the can. A related goal is therefore to mitigate this problem.

SUMMARY OF THE INVENTION

[0014] According to a first aspect of the present invention, there is provided a can end for a can for pressurized contents, the can end being configured to be joined by a peripheral annular joining portion to one axial end of a can body of the can and having an outer side arranged to face outwardly from the can and an inner side arranged to face inwardly into the can, the can end comprising: a central panel; a panel wall annularly surrounding the central panel and extending axially inwardly and radially outwardly from the central panel; an annular chuck wall structure extending radially- and axially-inwardly from the joining portion; and an annular bead which is connected between a radially outer edge of the panel wall and a radially inner edge of the chuck wall structure and which is concave with respect to the outer side of the

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can end and extends at least partially radially outwardly with respect to the radially inner edge of the chuck wall structure, wherein wall portions adjacent inner and outer ends of the concave annular bead form a bead mouth that is open towards the outer side of the can end.

[0015] The bead mouth may be the point of closest approximation of the wall portions adjacent inner and outer ends of the concave annular bead.

[0016] In one embodiment, the annular bead exhibits a cross-sectional profile which, in a plane through the can end which includes a central axis of the can end, substantially inscribes a circle. In this case, the annular bead may be open to the outer side in a direction radially inwardly and axially outwardly from the inscribed circle.

[0017] In an embodiment of the first aspect, in a plane through the can end which includes a central axis of the can end, the adjacent wall portions forming the bead mouth are parallel or diverge from the inner and outer ends of the annular bead towards the outer side of the can end.

[0018] According to a second aspect of the present invention, there is provided a can end for a can for pressurized contents, the can end being configured to be joined by a peripheral annular joining portion to one axial end of a can body of the can and having an outer side arranged to face outwardly from the can and an inner side arranged to face inwardly into the can, the can end comprising: a central panel; a panel wall annularly surrounding the central panel and extending axially inwardly and radially outwardly from the central panel; an annular chuck wall structure extending radially- and axially-inwardly from the joining portion; and an annular bead which is connected between a radially outer edge of the panel wall and a radially inner edge of the chuck wall structure and which is concave with respect to the outer side of the can end and extends at least partially radially outwardly with respect to the radially inner edge of the chuck wall structure, wherein the annular bead exhibits a cross-sectional profile which, in a plane through the can end which includes a central axis of the can end, substantially inscribes a circle, and wherein wall portions adjacent inner and outer ends of the annular bead form a bead mouth that is disposed axially outwardly and radially inwardly of the inscribed circle.

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[0019] The bead mouth may be the point of closest approximation of the adjacent wall portions nearest to the centre of said inscribed circle.

[0020] In embodiments of the first and second aspect, the panel wall may be convexly curved with respect to the can end outer side, wherein the chuck wall structure includes an annular chuck wall extending radially- and axially-inwardly, and the radially inner end of the annular chuck wall is connected to the annular bead via a portion which is convexly curved with respect to the can end outer side and which does not touch the outer side surface of the panel wall, and wherein the can end is configured such that, when the can end is joined to a can body and internal pressure in the can is increased so as to cause the can end to bulge outwardly, the convexly curved panel wall will kiss against the convexly curved portion at the radially inner end of the annular chuck wall.

[0021] The annular bead may exhibit a cross-sectional profile which, in a plane through the can end which includes a central axis of the can end, has a bead wall that is substantially continuously concavely curved through more than 180 degrees, and said concave bead wall may terminate at its outer end at an angle with respect to the central axis of the can end of not less than 45 degrees, said angle being measured in the cross-sectional plane from the central axis in the outward direction to the tangent to the panel wall at the radially outer end of the concave curvature in the direction of the bead wall moving from the central panel to the chuck wall.

[0022] In this case, the panel wall may blend at its radially outer edge into the concave curvature of the annular bead, and, in said plane through the can end, a tangent to the wall of the can end at the transition point between the convex panel wall and the concave annular bead, in a radially outward direction, may be at an angle from the outer axial direction of not more than 150 degrees, measured in said plane.

[0023] In embodiments of the invention, the panel wall may be convexly curved with respect to the outer side of the can end, and blends at its radially outer edge into the concave curvature of the annular bead, which maintains a substantially constant curvature through more than 180 degrees, and wherein, in a plane through the can end which includes a central axis of the can end, a tangent to the wall of the can end at the transition point between the convex panel wall and the concave annular bead,

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in a radially outward direction, is at an angle from the outer axial direction of not more than 150 degrees, measured in said plane.

[0024] In these and other embodiments, the annular bead may be substantially continuously curved through more than 225 degrees. The angle of the tangent to the wall of the can end at the transition point from the axial outer direction may be not more than 135 degrees.

[0025] According to a third aspect of the present invention, there is provided a can end for a can for pressurized contents, the can end being configured to be joined by a peripheral annular joining portion to one axial end of a can body of the can and having an outer side arranged to face outwardly from the can and an inner side arranged to face inwardly into the can, the can end comprising: a central panel; a panel wall annularly surrounding the central panel and extending axially inwardly and radially outwardly from the central panel; an annular chuck wall structure extending radially- and axially-inwardly from the joining portion; and an annular bead which is connected between a radially outer edge of the panel wall and a radially inner edge of the chuck wall structure and which is concave with respect to the outer side of the can end and extends at least partially radially outwardly with respect to the radially inner edge of the chuck wall structure, wherein said panel wall and said annular bead are integrally formed by reforming a blank by axially compressing it against an inner centre panel tool that has an axially inwardly and radially outwardly sloped surface extending from a central panel region and is provided at its peripheral radially outer edge with a curved annular recess facing the outer side, said curved annular recess thereby forming said annular bead.

[0026] According to a fourth aspect of the present invention, there is provided a can end for a can for pressurized contents, the can end being configured to be joined by a peripheral annular joining portion to one axial end of a can body of the can and having an outer side arranged to face outwardly from the can and an inner side arranged to face inwardly into the can, the can end comprising: a central panel; a panel wall annularly surrounding the central panel and extending axially inwardly and radially outwardly from the central panel; an annular chuck wall structure extending radially- and axially-inwardly from the joining portion; and an annular bead which is connected between a radially outer edge of the panel wall and a radially inner edge of the chuck wall structure and which is concave with respect to the outer side of the can end and extends at least partially radially outwardly with respect to the radially

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inner edge of the chuck wall structure, wherein the material of the can end is not folded or in contact with itself between the radially outer edge of the panel wall and the radially inner edge of the chuck wall structure.

[0027] The can end of any of the above aspects and embodiments may further comprise a cover, label, token, tab or other material provided in the annular bead.

[0028] According to a fifth aspect of the present invention, there is provided a method of manufacturing a can end comprising: reforming a blank by compressing an axially extending annular portion of the blank material that surrounds a central panel region of the blank to cause at least a radially inner portion of the annular portion to flow into and substantially adopt the shape of an annular recess provided on the opposite side of the central panel, in the axial direction, to the direction in which the annular portion initially axially extends; and further reforming the blank under axial compression with at least the central panel region of the blank under tension.

[0029] In embodiments of this method, reforming the blank may include axially compressing the annular portion against an annular tool surface extending radially outwardly from the central panel region and curving axially away from the direction in which the annular portion of the blank initially axially extends and terminating in a concave annular recess that faces back towards the direction in which the annular portion initially axially extends, such that at least the radially innermost portion of the annular portion rolls radially outwardly around the annular tool surface from the radially outer edge of the central panel region to substantially adopt the shape of said annular tool surface.

[0030] The annular recess may include at the radially outer edge thereof an annular concave portion facing axially outwardly and configured to promote the formation of an axially outwardly concave and radially outwardly extending bead portion.

[0031] Embodiments of the method include axially compressing the blank to cause at least the radially inner portion of the annular portion to flow into and substantially adopt the shape of the annular recess imparts a preliminary radially inward curve in a remaining portion of the annular portion that otherwise extends axially from the

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radially outer edge of the annular recess to an or the outermost peripheral portion of the blank that is held to facilitate said axial compression.

[0032] Here, reforming the blank may include further axially compressing the blank to cause said preliminary radially inward curve in the remaining portion of the annular portion to further deform radially inwardly.

[0033] Moreover, further axially compressing the blank may include supporting an axially outer side of the remaining portion of the annular portion by an outer chuck wall tool, so that the axial outer end of the radially inwardly curved remaining portion is at least partially formed into at least part of a chuck wall of the end can by said further axial compression.

[0034] In embodiments of the method, all of the reforming and further reforming is performed by a single motion to progressively axially compress and reform the annular portion of the blank.

[0035] According to a sixth aspect of the present invention, there is provided a method of manufacturing a can end comprising: reforming a blank by compressing an axially extending annular portion of the blank material that surrounds a central panel region of the blank against an annular tool surface extending radially outwardly from the central panel region and curving axially away from the direction in which the annular portion of the blank initially axially extends and terminating in a concave annular recess that faces back towards the direction in which the annular portion initially axially extends, such that at least the radially innermost portion of the annular portion rolls radially outwardly around the annular tool surface from the radially outer edge of the central panel region to substantially adopt the shape of said annular tool surface.

[0036] Embodiments of the fifth or sixth aspect may further include axially drawing the blank by drawing an outermost peripheral portion of the blank in an axially outward direction relative to the central panel region of the blank in order to draw an intermediate annular portion of the blank such that it extends radially- and axially-outwardly from the central panel region to the outermost peripheral portion as said axially extending annular portion.

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[0037] Axially drawing the blank may introduce a preliminary radially outward curve into the annular portion of the blank in the vicinity of the central panel region of the blank.

[0038] According to a seventh aspect of the present invention, there is provided an inner centre panel tool for pressing against the inner side of a blank in the manufacture of a can end to reform the blank against said tool, the tool comprising an axially outwardly facing central panel region and a sloped peripheral surface extending axially inwardly and radially outwardly from the central panel region and terminating at its radially outer peripheral edge in a concave annular recess facing in the axially outward direction.

[0039] In embodiments of the tool, said sloped peripheral surface curves gradually axially inwardly away from the central panel region in the radially outward direction to form said slope as a domed convex annulus.

[0040] In further embodiments of the tool, said concave annular recess is concavely curved.

[0041] According to an eighth aspect of the present invention, there is provided tooling for manufacturing a can end to be joined to one axial end of a can body of a can for pressurized contents, comprising: an inner centre panel tool for forming the inner side of a can end corresponding to the inside of the can and arranged to be disposed concentrically within an inner wall tool so as to be substantially adjacent to a radially inside wall of the inner wall tool, wherein said inner centre panel tool has a peripheral surface sloping axially inwardly in a radially outward direction from a central panel region of the inner centre panel tool, such that said peripheral surface together with said inside wall of the inner wall tool defines an annular recess axially inwardly of the central panel region, and wherein said annular recess is configured to promote the formation of a radially outwardly extending bead in a can end during a reform process of axially compressing a blank against the inner centre panel tool.

[0042] In embodiments of the tooling, said peripheral surface is sloped relative to the axial direction across at least 25% of the radial width of said annular recess extending radially outwardly from said central panel region.

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[0043] In further embodiments of the tooling, an axially outwardly facing concave annular recess is formed at the radially outer edge of the peripheral surface of the inner centre panel tool, so as, together with the inside wall of the inner wall tool, to promote said formation of the radially outwardly extending bead during the reform process of axially compressing a blank against the inner centre panel tool.

[0044] In still further embodiment of the tooling, said peripheral surface is convexly curved gradually axially inwardly away from the central panel region in the radially outward direction to form said slope as a domed convex annulus.

[0045] According to a ninth aspect of the present invention, there is provided tooling for manufacturing a can end to be double-seamed onto one axial end of a can body of a can, comprising: inner tools for forming the can end on a side corresponding to the inside of the can and arranged to be disposed on an axially inner side of outer tools for forming the can end on a side corresponding to the outside of the can, including: an inner centre panel tool; an inner wall tool arranged concentrically surrounding and substantially adjacent to the inner centre panel tool; an outer centre panel tool opposed to the inner centre panel tool; and at least one outer wall tool generally opposed to the inner wall tool and arranged concentrically surrounding and substantially adjacent to the outer centre panel tool, wherein the opposed inner and outer wall tools are able to move axially relative to the opposed inner and outer centre panel tools, wherein the outer centre panel tool has a smaller outside diameter than the inside diameter of a radially inner wall of the inner wall tool, the outer centre panel tool being disposable concentrically at least partially within the inner wall tool to leave an annular gap radially surrounding the outer centre panel tool, and wherein the inner centre panel tool includes a peripheral annular surface surrounding a central panel region of the inner centre panel tool and extending axially inwardly in a radially outward direction from the central panel region, the peripheral annular surface, together with the radially inner wall of the inner wall tool, defining an annular recess extending axially inwardly from the central panel region of the inner centre panel tool, said annular recess being substantially opposed to said annular gap.

[0046] In embodiments of this tooling, the peripheral annular surface terminates at its radially outer end in an annular recess configured to promote the formation of a radially outwardly extending recess during a reform process of axially compressing a blank against the inner centre panel tool.

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[0047] The at least one outer wall tool may include a chuck wall tool arranged concentrically surrounding and substantially adjacent to the outer centre panel tool and extending across the annular gap substantially opposed to the annular recess.

[0048] Here, the chuck wall tool may include an axially inwardly facing annular surface opposed to the annular recess, said inwardly facing surface being sloped axially outwardly in the radially outward direction.

[0049] According to a tenth aspect of the present invention, there is provided a can for pressurized contents comprising a can body having a can end joined to one axial end thereof, the can end being selected from the group consisting of: the can end of any one of the first to fourth aspects; a can end manufactured by the method of the fifth or sixth aspects; a can end made using the tool of the seventh aspect; and a can end made using the tooling of the eighth or ninth aspects.

[0050] According to an eleventh aspect of the present invention, there is provided a can end manufacturing apparatus configured to manufacture a can end according to the method of the fifth or sixth aspects.

[0051] This apparatus may comprise the tool of any one of the seventh aspect; and/or the tooling of the eighth or ninth aspect.

[0052] According to a twelfth aspect of the present invention, there is provided can end manufacturing apparatus including: the tool of the seventh aspect; and/or the tooling of the eighth or ninth aspect.

[0053] According to a thirteenth aspect of the present invention, there is provided a can end, the can end being configured to be joined by a peripheral annular joining portion to one axial end of a can body of the can and having an outer side arranged to face outwardly from the can and an inner side arranged to face inwardly into the can, the can end comprising: an annular structure which is concave with respect to the outer side of the can end and is connected to: a centre panel structure radially inside the annular structure; and a chuck wall structure annularly surrounding the annular structure and extending axially- and radially- outwardly from the annular structure; and a cover, label, token or tab, or other material, provided at least partially within the concave annular structure.

[0054] Embodiments of this can end may be for a can for pressurized contents and may be arranged such that, when the can end is joined to a can body and internal pressure in the can is increased, the can end will be deformed such that wall portions at each side of the annular structure close on the cover, label, token, tab or other material provided in the concave annular structure.

[0055] In further embodiments of the can end, the cover, label, token or tab may substantially enclose an opening of the can end to maintain a sterile or hygienic condition on the enclosed outer side surface of the can.

[0056] In still further embodiments of the can end, the cover, label, token or tab may cooperate with or form part of an opening and/or re-sealing feature of the can end.

[0057] In even further embodiments of the can end, the cover, label, token, tab or other material may be provided in the concave annular structure to provide reinforcement or to control the deflection and/or failure behaviour of the can end.

[0058] Further aspects and embodiments are disclosed in the claims and description of Annex 1, the content and disclosure of which is incorporated herein and forms part of the present specification.

[0059] The can end of the present invention can be considered as having a centre panel structure, including a substantially flat centre panel and a radially outwardly, axially inwardly sloping panel wall, and a chuck wall structure including a chuck wall with a curved transition at its radially- and axially-inner end and connected at its radially- and axially-outer end to a joining portion. The centre panel structure advantageously exhibits a larger outer diameter than the inner diameter of an opening formed by the radially- and axially-inner edge of the chuck wall structure, and lies at least partially axially inside the chuck wall structure so that the chuck wall structure resists the centre panel structure from passing axially outwardly through the opening when a can including the can end is pressurized.

[0060] Characteristic features of the can end of the present invention include an annular bead surrounding the centre panel structure acting as a reinforcing ring to resist outward doming of the centre panel which tends to pull the peripheral edge of the centre panel radially inwardly.

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[0061] The annular ring is connected between the centre panel structure and the chuck wall structure, and extends radially outwardly relative to an inner peripheral edge of the surrounding chuck wall structure. The annular bead is concavely curved facing radially inwardly.

[0062] The radially outwardly, axially inwardly sloping panel wall forms, together with the centre panel, a domed structure that is convex in the axially outward direction to function as a pseudo-pressure vessel to transfer forces from the centre panel to the annular bead without inducing substantial bending moments in the centre panel. The sloping panel wall is preferably convexly curved, and may be continuously curved to blend at one end with the centre panel and at the other end with the annular bead.

[0063] The curved transition at the radially- and axially-inner end of the chuck wall structure is also preferably continuously curved to blend with the chuck wall and the opposite end of the annular bead. Alternatively, the curved transition may include one or more straight portions. The curved transition is convexly curved, facing in the radially inward direction, and acts as an annular bead strengthening the opening formed by the radially inner edge of the chuck wall structure.

[0064] The can end may be configured so that when a can including the can end is pressurized sufficiently to deform the can end, the can end will exhibit a progressive failure mode. This may be achieved by the panel wall and the transition at the radially inner edge of the chuck wall structure both being convexly curved and arranged so that, as the can end is deformed axially outwardly, they will kiss, cam or roll against or relative to each other, without the can end failing at a unique circumferential point of weakness.

[0065] The improved performance of the can end allows it to be manufactured from thinner sheet metal, and its geometry may be adjusted to use the same area of metal as or less than that of can ends of the prior art.

[0066] An inner centre panel tool of the present invention has a peripheral forming surface that slopes radially outwardly and axially inwardly from a central panel region. The peripheral surface preferably extends gradually axially inwardly from the peripheral edge of the central panel region in the radially outward direction. The sloped forming surface is preferably continuously curved, and may, for example, exhibit an elliptical curvature or a constant radius of curvature. At the radially outer edge of the sloped forming surface, the inner centre panel tool has a concave annular ring with a radius of curvature that is small compared to the length of the convex forming surface, and which promotes the formation of an annular bead when a blank is pressed against the inner centre panel tool. The concave annular recess is preferably curved, and in some embodiments may have a substantially constant radius of curvature.

[0067] The concave annular recess terminates at the radially outer edge of the inner centre panel tool in an axially outward peak. The peak may advantageously blend the curvature of the concave annular recess with the radially inner wall of an inner wall tool that is arranged to substantially adjacently surround the inner centre panel tool during formation of a can end. Such tooling according to the present invention defines an annular recess, axially inwardly of the centre panel region of the inner centre panel tool, between the inner centre panel tool and the inner wall tool, into which axially drawn material of a blank may be reformed under axial compression. The peripheral surface may advantageously be sloped radially outwardly and axially inwardly in such a manner that, when a blank is pressed against the inner centre panel tool, a centre panel and/or a panel wall region of the blank will be brought into tension.

[0068] Tooling according to the present invention may include the inner centre panel tool and inner wall tool on an axially inner side, opposed to outer tools including an outer centre panel tool and at least one outer wall tool. The outer centre panel tool has a diameter smaller than the diameter of the inner centre panel tool, and may be at least partially disposed inside the inner wall tool to leave an annular gap. A blank which is axially outwardly drawn across the annular gap may be reformed against the inner centre panel tool in a single axial compression motion, by moving the opposed inner and outer wall tools axially inwardly relative to the opposed inner and outer centre panel tools. A characteristic of the tooling is that the annular recess formed by the inner tools opposes the annular gap between the outer centre panel tool and the inner wall tool.

[0069] The method of manufacturing a can end according to the present invention involves axially compressing an axially drawn blank to reform the axially drawn portion in a single step to produce the panel wall, annular bead and curved transition which extend between the centre panel and chuck wall of the can end.

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Advantageously, the step of axially compressing the blank serves to bring the centre panel region of the blank under tension, increasing the rigidity and reducing floppiness of the centre panel of the can end.

[0070] The reform method desirably imparts a series of preliminary curves at different stages, which, under further axial compression, collapse and plastically deform to form the desired can end wall features. The method may also involve pressing the axially extending wall of the drawn blank into an annular recess that includes a curved concave annular recess which tends to promote formation of the tightly rolled annular bead.

[0071] Advantageously, the tooling and manufacturing method of the present invention can be implemented with existing can end pressing machines, and so the can ends of the present invention can be made without substantial changes to the manufacturing equipment or the need to buy new manufacturing plant.

[0072] Alternatively, the reforming method may be carried out in a separate press or tooling station to that in which the blank is drawn. Carrying out the reforming operation in a separate press may be desirable if it is easier to handle the taller drawn blank through other machinery for carrying out related operations (for example, to curl, score, emboss, etc.) than the shorter reformed end. In this case, the reforming process can be used to remove any slackness that may arise in the centre panel, caused, for example, by a scoring or embossing operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0073] In order to enable a better understanding of the present invention, and to show how the same may be carried into effect, reference will now be made, by way of example only, to the accompanying drawings, in which:-

[0074] Figure 1 shows a cross-sectional view of a conventional can end in a plane through the can end which includes the central axis of rotation of the can end;

[0075] Figure 2 shows a cross-sectional view of an embodiment of a can end according to the present invention in a plane through the can end which includes the central axis of rotation of the can end, omitting any detailed features of the centre panel of the can end;

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[0076] Figure 3 shows a plan view of the can end shown in Figure 2;

[0077] Figure 4 shows a similar cross-sectional view to that of Figure 2, of the can end of Figures 2 and 3;

[0078] Figure 4A shows an enlarged view of the portion of the cross-sectional view circled in Figure 4;

[0079] Figure 5 shows an enlarged view in the same cross-sectional plane as Figures 4 and 4A, illustrating detail of a bead and chuck wall portion of the can end;

[0080] Figure 6 shows a superimposed sequence of schematic cross-sectional images of the embodiment of the can end of Figures 2 to 5 double-seamed onto one axial end of a can body of a can, in a plane through the can which includes the central axis of rotation of the can body and can end, illustrating deflection of the can end due to internal pressurization of the can, together with an enlargement of the circled portion which includes the bead and chuck wall portion of the can end;

[0081] Figure 6A shows, in sequence, separate schematic cross-sectional views (a) to (d) of each superimposed image of Figure 6, as the can end deflects under increasing internal pressurization of the can, together with corresponding enlarged views of the circled portion of each image which includes the bead and chuck wall portion of the can end;

[0082] Figures 6B and 6C show corresponding views as for Figures 6 and 6A, for an alternative embodiment in which the can end is initially formed with the panel wall and curved transition region touching, so that the mouth is closed, and where the mouth remains closed as the can end deflects under pressurization;

[0083] Figures 6D and 6E show corresponding views as for Figures 6 and 6A, for an alternative embodiment in which the can end is initially formed with the panel wall and curved transition region not in contact, so that the mouth is open, and where the mouth remains open as the can end deflects under pressurization;

[0084] Figure 7 shows another enlarged detail view, similar to that of Figure 5, illustrating certain important features of the embodiment of the can end of Figures 2 to 6, and of an embodiment of tooling according to the present invention which may

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be used to form such a can end from a blank, in a plane through the can end which includes the central axis of rotation of the can end;

[0085] Figure 8 is a similar view to that of Figure 7, illustrating further features of the tooling which may be used to form the can end;

[0086] Figures 9, 10 and 11 show an embodiment of tooling according to the present invention, suitable for forming the can end of Figures 2 to 7 from a blank, at different axial positions which illustrate forming an annular bead of the can end under axial compression;

[0087] Figures 9A to 11A show enlarged cross-sectional views of the circled portions of the tooling of Figures 9, 10 and 11, respectively, together with a blank being formed into the can end, in a plane through the can end which includes the central axis of rotation of the can end;

[0088] Figure 12 shows an enlarged cross-sectional view of a can end and the related tooling of Figures 7 to 11, in a plane through the can end which includes the central axis of rotation of the can end, illustrating schematically how material flow is induced in the blank to bring the centre panel and/or panel wall portions under tension during axial compression for forming a can end from the blank;

[0089] Figures 13 to 17 show a series of enlarged cross-sectional views of an embodiment of tooling according to the present invention in a plane through the tooling which includes a central axis of rotation of the blank from which an embodiment of a can end according to the present invention is formed, and sequential steps in the formation of such a can end thereby;

[0090] Figure 18 shows an enlarged view, similar to Figure 4A, of the bead and chuck wall portion of another embodiment of a can end according to the present invention, where side walls defining the bead mouth are parallel;

[0091] Figure 19 shows an enlarged view, similar to Figure 4A, of the bead and chuck wall portion of a further embodiment of a can end according to the present invention, where side walls defining the bead mouth are diverging;

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[0092] Figure 20 shows an enlarged view, similar to Figure 4A, of the bead and chuck wall portion of still another embodiment of a can end according to the present invention, where the panel wall is substantially straight between the centre panel and the bead; and

[0093] Figure 21 shows an enlarged view, similar to Figure 4A, of the bead and chuck wall portion of still another embodiment of a can end according to the present invention, where a cover, label, token or tab is schematically indicated as being provided in the concave annular structure formed with the bead.

DETAILED DESCRIPTION

[0094] In the following description, a can end is formed from a circular blank of material, exhibiting a central axis of rotational symmetry, shown as axis X in Figures 3 and 4. This axis of the blank, which corresponds to the central axis of a can end formed from the blank, is used throughout the present description to define the axial direction of the blank, the can end, a can body, and a can having the can end of the present invention attached to the can body, as well as the central axis of associated tools and tooling by which the can end may be formed. In the embodiments illustrated and described herein, these all have a common central axis.

[0095] The upper side of the can end shown in Figure 2 corresponds to the side of the can end which will be exposed, externally, after the can end has been joined to one axial end of a can body. Similarly, the lower side of the can end shown in Figure 2 corresponds to the side of the can end which will be inside the can, after it has been joined to one axial end of a can body. These two sides of the can end are therefore referred to, correspondingly, as the outer side and the inner side of the can end. Likewise, throughout the present description, references to the outer side and to the outer axial direction are made with respect to the direction which the outer side of the can faces, whilst references to the inner side or inner axial direction are references to the direction in which the inner side of the can faces.

[0096] A similar convention is used to define the tools and tooling by which the can end according to the present invention may be made. Accordingly, an “inner tool” is a tool which opposes an inner side of a blank in order to form the can end, whilst an “outer tool” is a tool which opposes the outer side of the blank for forming a can end.

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[0097] This frame of reference, and such labelling, will be used throughout, unless it is explicitly stated that a non-axial direction is being described. For example, in the radial direction, reference will be made to the radially inward and radially outward directions, or to the radially inside or radially outside surfaces of various components, in which case it is clear that the radial direction, rather than the axial direction, is being described.

[0098] Referring to Figure 1, it is helpful, as a preliminary measure, to consider the construction of a conventional can end 500.

[0099] The can end 500 shown in Figure 1 has a generally circular shape, as viewed in axial plan view, and is shown in Figure 1 as a cross-sectional view of the can end 500 in a plane through the can end which includes the central axis of the can end. The can end 500 shown in Figure 1 is illustrated schematically, and is rotationally symmetric about its central axis. The can end is shown in its originally formed condition, having been formed from a circular blank, before attachment to the end of a can body. The schematic view of Figure 1 omits any details which might typically be applied to the circular centre panel of a can end, such as a tab and related structure by which an opening or aperture in the can end can be opened.

[00100] As can be seen in Figure 1, such a can end includes a circular centre panel 518, surrounded by an annular countersink 516 which is concave with respect to the outer side of the can end 500.

[0100] The can end 500 of Figure 1 is configured to be double-seamed to the axial end of a can body, and accordingly includes a cover hook 524 and a seaming panel 526. A chuck wall 514 extends from the concave countersink 516 in an axially outward and radially outward direction, and is connected to the seaming panel 526 via a seam transition 512. The can end 500 may be connected to the axial end of a can body by seaming the cover hook 524 and seaming panel 526 onto the end of the can body using a rotational chuck, in a well-known fashion.

[0101] At the radially-and axially-inner end of the chuck wall 514, the chuck wall 514 is connected to the upper end of a radially-outer wall 517 of the countersink 516, via a curved transition 550. The radially outer wall 517 of the countersink 516 is generally referred to as a “vertical” wall, due to it being aligned with the central axis of the can end.

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[0102] The countersink 516, similarly, includes a vertical radially inner wall 515, substantially aligned with the axial direction of the can end. The radially inner wall of the countersink 516 is connected to the peripheral edge of the circular centre panel 518 of the can end 500 via a curved transition 520. It can be appreciated from the view shown in Figure 1 how the curved transition 520 represents a relatively tight bend between the substantially flat centre panel 518 and the axially aligned vertical wall 515 constituting the radially inner wall of the countersink 516. This sharp transition 520 between the vertical radially inner wall 515 of the countersink 516 and the circular centre panel 518 makes it difficult for tensile forces in the centre panel 518 to be transmitted into the vertical radially inner wall 515 of the countersink 516 when the can end 500 is fitted to the axial end of a can body and the can is pressurized. As a result, the internal pressurization of the can can result in the centre panel 518 becoming domed in the axially outward direction, as schematically shown in Figure 1.

[0103] Although the structure shown in Figure 1 is generally a strong one, able to withstand large internal pressures with only a small thickness of material, it has nevertheless been found to exhibit an undesirable “peak and leak” failure mode, as discussed above. This is understood to be due to the countersink 516 not having a progressive failure mode, such that the can end 500 will tend to fail at one specific point of weakness around the circumference of the countersink 516, at which point the structural integrity of the countersink 516 tends to fail critically, resulting in the centre panel 518 collapsing at one point across its diameter and bending outwards across that diameter, often accompanied by a leaking at one or more points.

[0104] The structure of the can end 500 shown in Figure 1 provides several important advantages. Primary among these is the provision of the chuck wall 514, which lies at an inclined angle to the axial, longitudinal direction of the can body onto which it becomes seamed. Once the double seam has been formed between the seaming panel 526 and the axial end of the can body, internal pressure within the can is transmitted to the seam via the inclined chuck wall 514. In can ends predating the can end of Figure 1, the material between the centre panel of the can and the seam consisted of a substantially vertical, axially-aligned wall section. Such arrangements meant that any pressure applied to the inner surface of the centre panel would be transmitted directly in an axial direction to the seam, which could eventually result in a failure mode where the seam itself failed and the can end separated from the can body.

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[0105] With the inclined chuck wall 514, however, the forces imparted by the internal pressure of the can acting on the inner surface of the centre panel 518 could be transmitted partly axially and partly radially to the seam, in such a manner that induces hoop stresses in the seam which tend to force the seam more tightly closed, rather than to cause the seam to unravel. This inclined chuck wall is consequently a desirable structural element. Another benefit of the inclined chuck wall 514 is that it reduces the peripheral diameter of the centre panel 518, for a given diameter of can body, by providing a radial separation between the edge of the centre panel 518 and the seam. A consequence of this reduced diameter of the centre panel 518 is that the extent to which the centre of the centre panel 518 deflects, and consequently the tendency of any associated opening tab to rise above the level of the seam, is reduced, for a given thickness of the centre panel 518.

[0106] Figures 2 to 5 all show a can end 10 which is an embodiment of the present invention. The same can end 10 is shown attached to a can body in Figures 6 and 6A, and is the can end resulting from the use of the tools and tooling and associated method which will be described in relation to Figures 7 to 17.

[0107] Turning to Figure 2, there is shown a cross-sectional view of a can end 10 according to a embodiment of the present invention, in a plane through the can end which includes the central axis X, being an axis of rotational symmetry, of the can end 10.

[0108] The can end of Figure 2 is similar to that shown in Figure 1 in terms of the provision of an angled chuck wall 14 connected by a seam transition 12 to a seaming panel 26 and cover hook 24, by which the can end can be double-seamed to one axial end of a can body of a can.

[0109] As with the chuck wall 514 of the can end 500 of Figure 1, the chuck wall 14 of the can end 10 of Figure 2 extends radially inwardly and axially inwardly from the seam transition 12. Chuck wall 14 of can end 10 functions in substantially the same way as chuck wall 514 of the can end 500 of Figure 1, and so provides the same advantages and benefits for the can end 10 as mentioned above for the chuck wall 514 of the can end 500 of Figure 1.

[0110] The can end 10 of Figure 2 is also provided with a substantially flat centre panel 18, similar to the centre panel 518 of the can end 500 of Figure 1.

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[0111] The can end 10 of Figure 2 differs from that of Figure 1, however, in several important, critical respects.

[0112] In place of the countersink 516 of the can end 500 of Figure 1, the can end 10 of Figure 2 is provided with an annular bead 16 extending around the circular centre panel 18, connected between the centre panel 18 and the chuck wall 14. As with the can end 500 of Figure 1, the can end 10 of Figure 2 is rotationally symmetric about a central axis of rotation X, as shown in Figures 3 and 4, meaning that the cross-sectional shape of a panel wall 20, the annular bead 16, a curved transition 50 between the bead and chuck wall, the chuck wall 14, seam transition 12, seaming panel 26 and cover hook 24 is substantially constant around the whole circumference. Figure 3 is a plan view of the can end of Figure 2, showing that the can end is circular in axial plan view.

[0113] As explained above in relation to the can end 500 of Figure 1, the can end 10 of Figure 2 is shown in the originally formed, un-seamed condition, prior to attachment to the axial end of a can body. As such, it is shown in a condition in which there are no stresses being imposed by internal pressure of the can.

[0114] Another important feature of the can end 10 of Figure 2 is that the centre panel 18 is provided around its peripheral edge with an annular panel wall 20, which extends radially outwardly and axially inwardly from the edge of the flat, circular centre panel 18.

[0115] In the example shown in Figure 2, the panel wall 20 is provided as a curved or domed annulus, which curves gradually away from the centre panel 18 in the axially inward direction, going from the centre panel 18 in the radially outward direction. This results in an outwardly convex dome, with a substantially flat centre panel 18.

[0116] In the example shown in Figure 2, the curved annular panel wall 20 is of substantially constant curvature, and blends at its radially inner end 34 into the flat centre panel 18. It is, however, contemplated that the panel wall 20 could have a non-constant curvature, and may even have one or more straight, but sloped, sections.

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[0117] Furthermore, although the centre panel 18 is shown as being substantially flat, the skilled person will understand that the centre panel 18 can, and typically will, be provided with additional features. Such features may include scoring, embossing, tab attachment, lettering or the formation of one or more apertures. Any aperture or apertures may be curled to accommodate closing devices or valves, and the centre panel 18 may be shaped to suit these.

[0118] It is, as well, known to provide strengthening features such as intermediate steps or outwardly convex beading to the centre panel 18, in order to provide further rigidity to the centre panel. The present invention is intended to encompass all such modifications to the structure of the centre panel 18, and there is intended to be no limitation in this respect, to the extent that it does not negatively impact on the structural strength and integrity of the remaining features of the can end lying peripherally outside the circular centre panel 18.

[0119] The curved panel wall 20 functions as an approximation of an ideally-shaped pressure vessel, being outwardly domed so able to transmit tensile forces induced radially in the centre panel 18 through the panel wall 20 in an increasingly axial direction. This has the effect of reducing bending moments in the panel wall 20 and at the peripheral edge 30 of the circular centre panel, with the effect that the centre panel 18 will tend to remain substantially flat without excessive outward doming, and will deflect less due to internal pressurization of the can to which can end 10 is joined.

[0120] The axially inner, radially outer end 38 of the panel wall 20 is connected to the annular bead 16. Annular bead 16 is, in the example shown, a tightly rolled section of the can end wall, maintaining a substantially constant curvature through more than 180 degrees in cross-section, moving along the can end wall from the centre panel 18 in the radially outward direction.

[0121] The tightly rolled annular bead 16 tends to act as a reinforcing ring, and provides a structurally strong anchor onto which the domed pressure-vessel structure of the centre panel 18 and panel wall 20 is anchored. The annular bead 16 can thus act like the outer wall of a drum, across which the centre panel 18 and the panel wall 20 are held under tension, like a stretched drum skin.

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[0122] This assists in maintaining the centre panel 18 flat, and so allows greater freedom in determining the size, shape and position of any opening or aperture feature to be formed on or in the centre panel 18. For example, in can ends prone to outward doming of the centre panel, where an aperture is formed offset from the centre of the centre panel, the deflection induced, when the end is joined to a can body and the body is pressurized, will not be even, and may result in points of weakness or stress concentration at associated circumferential points around the centre panel. This can lead to a non-progressive failure mode of the can end.

[0123] Similarly, if an aperture is to be formed in the centre panel and sealed by a closure, for example a re-sealable closure mechanism, then it is desirable for the aperture to distort evenly under pressurisation of the can, otherwise the seal between the closure mechanism and the aperture may be broken, resulting in leakage.

[0124] Re-closable beverage can ends, for example of the type described in WO2007/128810, typically require the formation of an aperture in the central panel. Typically, a circular component is inserted within the aperture to close the aperture and form a seal. It is often preferable for such an aperture to be offset from the centre of the central panel. This offset causes one side the aperture to be closer to the downwardly dependent reinforcing bead and therefore the periphery of the aperture becomes unevenly supported. Thus when the container is pressurised and doming occurs, the shape of the aperture alters, and a planar circular seal may become non-circular and/or non-planar and may leak as temperatures and pressures fluctuate.

[0125] Since, with the present structure, the centre panel 18 of the can end 10 reduces doming and maintains the centre panel 18 relatively flat, any uneven deformation or distortion of the aperture is minimised, even if the aperture is offset from the centre of the centre panel 18.

[0126] The annular bead 16 is connected, at its other end, to the radially- and axially-inner end 13 of the chuck wall 14 of the can end 10 via a curved transition section 50.

[0127] An important feature of the can end of Figure 2 is that the curved transition 50 defines a radially inner edge 50e of the chuck wall structure, and that this radially inner edge 50e overhangs the radially outer edge 16e of the annular bead 16.

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[0128] As seen in plan view in Figure 3, the radially inner edge 50e presents an aperture of a certain diameter d1. The annular bead 16, together with the panel wall 20 and centre panel 18, present a pseudo-pressure vessel structure, having an outer diameter d2. In simple terms, it can thus be seen that, when the can end is attached to a can body and the can is pressurized, the internal pressure will tend to push the pseudo-pressure vessel structure in the axially outward direction, but that this structure is of too large a diameter to fit through the hole presented by the radially inner edge 50e of the chuck wall structure. The centre panel structure is thus too big to pass axially outwardly through the aperture provided by the chuck wall structure.

[0129] Similarly as for the can end 500 of Figure 1, the chuck wall structure of Figure 2 serves to transmit the internal pressure of the can acting against the can end 10 in an axially- and radially-outward direction, into the seam. This, again, has a structure which is strong in resisting the compressive forces transmitted through the chuck wall 14, and which is not prone to unravelling of the double seam by which the can end 10 is attached to the axial end of the can body.

[0130] The peripheral attachment structure of the can end 10 can be seen in enlarged view in Figure 4A, which corresponds to the portion of the can end 10 that is circled in Figure 4.

[0131] In the present example, not only does the panel wall 20 blend smoothly into the circular centre panel 18, but it is also arranged to blend smoothly into the inner end 44 of the annular bead 16. Similarly, the curved transition region 50 between the outer end 48 of the annular bead 16 and the inner end 13 of the straight chuck wall 14 is smoothly blended from the outer end 48 of the bead 16 into the straight chuck wall 14.

[0132] In this regard, it should be noted that the term “chuck wall structure” is intended to encompass any structure extending from the radially inner edge 50e of the chuck wall structure to the seaming panel 26. Although in the illustrated embodiments of Figures 2 to 17 the chuck wall 14 is shown as being straight, the skilled person will be familiar with chuck walls having alternative structures. For example, the chuck wall may be convexly or concavely curved, with respect to the outer side of the can end 10, or may include one or more steps or angled portions along its length. The function and purpose of such structures is well known to the person skilled in the art, and they may be freely applied in combination with the

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remaining structure of the present can end 10. The present invention is intended to cover other such chuck wall structures than the straight wall 14 depicted in the enclosed drawings figures. Nevertheless, it is presently envisaged that the chuck wall 14 may be straight or include one or more straight portions.

[0133] As noted above, the outwardly concave, tightly curved structure of the annular bead 16 helps to give the bead it its structural strength, in particular its resistance to radially inward tensile forces. The curvature of the curved transition section 50 also provides a similar structural integrity to the radially inner edge 50e of the chuck wall structure. The curved transition may be continuously curved or may include straight portions. The structures 16 and 50 thus act as inner and outer annular bead structures.

[0134] The reason why an annular bead provides structural strength can be contemplated, in one way, by considering Figure 4A.

[0135] In this figure, the transition point 40 between the outer end 38 of the convexly curved panel wall 20 and the inner end 44 of the concavely curved annular bead 16 can be identified as the point of inflexion at which the curvature changes from convex to concave, with respect to the outer side of the can, moving in the radially outward direction from the centre panel 18 into the annular bead 16. However, if the transition is a straight section rather than a point of inflexion, then the outer end 38 of the panel wall 20 is taken as the end of the radially outermost concave portion of the panel wall 20 at the point where it ceases to be concave (i.e., where it goes straight), and the inner end 44 of the bead 16 is taken as the point that the concave curvature ceases (i.e., where it goes straight). The outer end 48 of the annular bead 16, again, can be identified as the point at which the concave curvature terminates, which in this case is the point of inflexion at which it instantaneously switches to an outwardly convex curvature of the curved transition 50.

[0136] The smooth transition between the panel wall 20 and the circular centre panel 18 can also be seen, and the transition point 30 is defined as being the end of the substantially flat centre panel 18, this being the same as the radially inner end 34 of the panel wall 20.

[0137] Returning to consideration of the annular bead 16, this is formed with a bead wall 46 between the bead wall inner end 44 and the bead wall outer end 48. As

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explained above, when the can end 10 is attached to the axial end of a can body and the can is internally pressurized, the internal pressure acts against the centre panel 18 and forces it in the outward direction. This force is transmitted through the panel wall 20 as tension, and thus applies a radially inward tension on the annular bead 16. However, as will be appreciated from Figure 4A, the annular bead 16 is concave also with respect to the radially inward direction, i.e., towards the central axis X of the can end 10, making it extremely resistant to any radially inward forces. As such, the annular bead 16 provides a strong resistance to radially inward pulling of the annular bead 16 due to the tensile forces generated in the circular centre panel 18 when the can is pressurized.

[0138] This can be contrasted, for example, with the behaviour of the centre panel region 518 of the end can 500 shown in Figure 1. As can be readily appreciated from inspecting the structure of the can end 500 of Figure 1, any tendency for pressure in the can to pull the countersink 516 in a radially inward direction is resisted, primarily, by the vertical inner and outer countersink walls 515 and 517. However, these present an essentially flat ring structure, which is much less resistant to radially inward deflection than the continuously curved, radially inwardly concave annular bead 16.

[0139] A key aspect of this structure, as visible in Figure 4A, is the radially outward direction of the bead wall 46 at its point 48 of connection with the curved wall section 50. Indeed, this can be characterized by acknowledging that the annular bead 16 extends radially outwardly relative to the radially inner end 50e of the chuck wall structure.

[0140] In the example shown in Figure 4A, the annular bead 16 is shown to have substantially constant curvature between the radially inner end 44 and radially outer end 46 (moving in the radially outward direction of the bead wall 46), although it is contemplated that suitable annular bead wall structures can be provided in which the curvature is not constant. Similarly, it is also contemplated that the curved transition wall 50 would be of non-constant curvature, although as shown in Figure 4A, the curvature is substantially constant between the outer end 48 of the bead wall 46 and the radially inner end 13 of the straight chuck wall 14.

[0141] The annular bead 16 is relatively tightly rolled in order to provide the structural strength to function as a reinforcing ring. As can be seen, the radius of curvature of the annular bead 16 is substantially smaller than the radius of curvature of the panel wall 20. It will also be appreciated that the radius of curvature of the curved transition 50 is also substantially smaller than the radius of curvature of the panel wall 20, and similar to the radius of curvature of the annular bead 16. This helps give the annular bead 16 and curved transition 50 their resistance to deflection radially inwardly or outwardly, respectively, while the more gradual curvature of the panel wall 20 helps to transfer tensile forces in the centre panel 18 into the annular bead 16 without generating unwanted high bending moments in the panel wall 20 or centre panel 18.

[0142] The annular bead 16 can be seen to substantially inscribe a circle, with the exception of an opening provided at a mouth m which is formed between the convexly curved panel wall 20 and the convexly curved transition section 50. The mouth m is the point of closest approximation between these two convexly curved structures, at the point of said closest approximation which is nearest to the centre of the circle inscribed by the annular bead 16. Another characteristic feature of the illustrated embodiment of the present invention is that, due to the axially inwardly and radially outwardly sloping nature of the panel wall 20, combined with the radially outwardly extending disposition of the annular bead 16, the mouth m is located axially outwardly and radially inwardly of the inscribed circle.

[0143] This outwardly-extending character of the annular bead portion 16 can also be expressed by considering the angle which the ends 44 and 48 of the annular bead wall 46 exhibit with respect to the central axis X of the can end 10.

[0144] As shown in Figure 5, the inner end 44 of the annular bead wall 46, at the point of the transition 40 between the panel wall 20 and the bead wall 46, exhibits an angle α relative to the axial direction of the can end 10.

[0145] This angle α is measured in the cross-sectional plain through the can end 10 which includes the central axis of rotation X. The angle is measured from the axially outward direction around to the tangent to the wall of the can end 10 at the radially inner end 44 of the bead wall 46. The angle α is measured between the outwards direction of the centre axis X and the tangential direction moving from the centre panel 18 along the can end wall in the radially outward direction. The angle α is the angle included between these two directions on the radially outer side of the

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central axis X, moving from the radially outwards direction around to the tangential direction.

[0146] As shown in Figure 5, the angle α is approximately 135 degrees. The angle α is preferably less than 180 degrees, more preferably less than 150 degrees, in order to obtain the beneficial effects associated with the sloped panel wall 20 approximating the behaviour of an ideal pressure vessel by transmitting the tensile forces in the circular centre panel from the centre panel 18 to the annular bead 16 under tension and with minimal induced bending moments.

[0147] At the opposite outer end 48 of the annular bead wall 46, the bead wall defines an angle β with respect to the outward axial direction. This angle is, again, measured as the tangent to the annular bead wall at the end of the concavely curved section of the annular bead wall 46, and is to be measured in the cross-sectional plane which includes the central axis of rotation X of the can end 10. The angle β is measured moving from the axially outward direction, radially inwardly to the tangent to the bead wall 46. The direction of the tangential wall to be taken is that in the direction of the wall moving from the centre panel 18, along the panel wall 20 and around the bead wall 46 in the radially outward direction, although the orientation of the bead wall 46 will actually be radially inwardly in such a direction at the end point 48.

[0148] As shown in Figure 5, the angle β is approximately 90 degrees, and in general is preferably more than 45 degrees, more preferably more than 60 degrees.

[0149] In both cases, the tangent will normally be the same at the end points 44 and 48 on both the inner side surface and the outer side surface; however, in the case of any discrepancy, the angle of the tangent to the inner side surface should be taken.

[0150] Figure 5 also indicates the angle θ, which is the angle of the chuck wall 14 in the axially- and radially-outward direction, relative to the axially outward direction. In the case of a straight chuck wall, the angle is that in the direction of the tangent to the chuck wall 14 on the outer side surface of the can end 10. In the case of a chuck wall which is curved or which includes further annular features such as angular connections, double angles or steps, etc., then the angle to be measured is the angle between the axially outer end of the curved transition portion 50, at the point where it

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ceases to be convex (corresponding to the point coterminous with inner end 13 of chuck wall 14 in the illustrated embodiment), and the axially inner end of the seam transition 12, at the point where it ceases to be convex (corresponding to the point coterminous with outer end 15 of chuck wall 14 in the illustrated embodiment).

[0151] The angle θ is preferably from 20 degrees to 70 degrees relative to the axial direction. A more preferred range for the angle θ is from 25 to 60 degrees, even more preferably between 33 and 50 degrees, and still more preferably about 45 degrees, albeit it is optional for the chuck wall 14 to be inclined.

[0152] Figure 6 shows a superimposed sequence of schematic cross-sectional images of the embodiment of the can end 10 of Figures 2 to 5 after it has been double-seamed onto one axial end of a can body of a can, in a plane through the can which includes the central axis of rotation of the can body and can end, illustrating deflection of the can end 10 due to internal pressurization of the can. Figure 6 also shows an enlargement of the circled portion of the superimposed images of Figure 6, including the bead and chuck wall portion of the can end as it deflects under internal pressurization of the can.

[0153] Figure 6A shows, in sequence, separate schematic cross-sectional views (a) to (d) of each superimposed image of Figure 6, as the can end deflects under increasing internal pressurization of the can, together with corresponding enlarged views of the circled portion of each image which includes the bead and chuck wall portion of the can end. These figures demonstrate the failure mode of the can end 10 when the pressure difference between the inside and the outside of the can is increased, with a higher internal pressure than external pressure.

[0154] Unlike in the case of the can end 500 shown in Figure 1, which may exhibit a sudden failure mode known as “peak and leak”, the can end 10 exhibits a progressive failure mode (and at a higher pressure, for a given thickness of the can end material). The reasons for this are believed to be as follows.

[0155] As noted above, the convex curved outer side surface of the panel wall 20 and the convex curved outer side surface of the curved transition 50 oppose each other at the mouth m of the annular bead portion 16. It is presently contemplated for the mouth m to be open to the outer side of the can end 10 in the pressed and formed can end, as shown in image (a) of Figure 6A, rather than for the opposed

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sides 20, 50 of the mouth m to come into contact when the end is pressed. Such a structure allows the concave annular groove to be cleaned and sterilised, and also prevents any surface treatments or coatings on the outer surface from being damaged.

[0156] With reference to Figure 21, one possible related advantage of an open-mouthed can end structure is that it permits the insertion of a cover, token, tab or label 200 within the mouth m, either before or after seaming onto the can body. The cover, token, tab or label 200 may be flexible (e.g., paper, card or plastic). Such a cover, token, tab or label 200 may provide a message or advertisement. As will be understood from the following description of the deflection behaviour, such a cover 200 might be inserted in the bead mouth m of the can end 10 before the can is pressurized, such as by being filled, and will be gripped due to the mouth m at least partially closing when the can is pressurized. That is to say that, the cover, label, token or tab 200 will be pressed between the wall portions on each side of the mouth m. In the present case, these wall portions are part of the panel wall 20 and the curved transition wall 50.

[0157] Such a cover, label, token or tab 200 may substantially enclose an opening of the can end, as typically provided in the centre panel 18, to maintain a sterile or hygienic condition on the enclosed outer side surface of the can end. This may prevent contamination of the can end opening, and so allow the contents of the can to be hygienically consumed directly from the can. Equally, the cover, label, token or tab 200 may cooperate with or form part of an opening and/or re-sealing feature of the can end 10. For example, the cover or similar structure might unfold to form a pouring spout, or may provide for the opening of the can to be sealed again after having been opened.

[0158] It will be clear that such features might be applied equally to a can end for a non-pressurized can, in which case the cover, label, token or tab 200 may be secured within the open mouth of the concave annular structure by adhesive or by pressing the walls at the sides of the mouth in such a way as to press onto the cover, label, token or tab 200, or by forming the cover, label, token or tab 200 of a thickness to fit tightly within the mouth m of the concave annular structure.

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[0159] A further possible advantage is that material may be deposited within the mouth m, for example to provide further reinforcement to the bead and/or to control the deflection and/or failure behaviour of the can end 10.

[0160] An open mouth structure, however, is not considered to be essential, and the present invention is intended also to encompass examples where the mouth m' is formed with the opposed panel wall 20 and curved transition 50 in contact (see Figures 6B and 6C, for example).

[0161] Image (a) in Figure 6A illustrates the can end when double-seamed onto a can end and filled with pressurized contents under normal conditions. As shown in Figures 6 and 6A, when the internal pressure of the can to which the can end 10 has been double-seamed is increased, or if the external pressure reduces, then the can end 10 will deflect under the influence of the pressure difference. This deflection acts to push the domed central panel region including the centre panel 18 and the sloped panel wall 20 in the axially outward direction. At the same time, the chuck wall 14 acts like a lever, and bends so as to deflect axially outwardly at the radially inside edge 50e of the chuck wall structure.

[0162] This movement forces the pseudo-pressure vessel of the centre panel 18 and sloping peripheral edge 20 into the opening defined by the radially inner edge 50e of the chuck wall structure, essentially plugging the hole. This causes the two opposed sides 20 and 50 of the mouth m to come into contact (if they were not already), as seen in image (b) of Figure 6A, and to cam against one another. This kissing of one surface against the other is shown at the point indicated by m' in images (b) and (c) of Figure 6A, where the mouth m closes.

[0163] It is believed that this causes the touching sides 20 and 50 to roll and slide against each other, and prevents any defect occurring at a single annular position. The result is that, with further deflection of the can end 10 axially outwardly, the centre panel 18 and the domed panel wall 20 eventually force their way through the aperture defined by the radially inner edge 50e of the chuck wall structure, and that in doing so the annular bead portion 16 and the curved transition portion 50 will eventually be uniformly and gradually unrolled as the pressure difference increases, without failing at a single point of weakness. When this occurs, the can end 10 is "flipped" inside out, as seen in image (d) of Figure 6A.

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[0164] During this process the chuck wall 14 is also gradually deflected outwardly in a progressive manner. At the same time, the angle of the chuck wall 14 serves to transmit compression forces radially outwardly, resisted by the folded rings of can end and can body material making up the double seam. This assists in maintaining the integrity of the double seam until after the can end 10 has actually flipped inside out.

[0165] The further effect of the domed centre panel structure 18, 20 coming into contact with the inner peripheral edge 50e of the chuck wall structure is that the chuck wall 14 acts to resist axially outward movement of the centre panel 18, and so further acts to prevent the occurrence of tab-above-seam, where an opening tab on the centre panel extends axially beyond the plane of the axially outermost edge of the seam. This can be appreciated from images (a), (b) and (c) of Figure 6A, which show how the domed centre panel 18 remains below the plane of the top of the double seam.

[0166] The deflection and failure mode shown in Figures 6 and 6A can be contrasted with that of two similar, alternative embodiments of the present invention, as shown in Figures 6B and 6C and in Figures 6D and 6E.

[0167] As seen in image (a) of Figure 6C, this can end is initially formed with a closed mouth m’. As would be expected, this very closely mirrors the behaviour of the can end 10 of Figures 6 and 6A, with the chuck wall 14 resisting outward movement of the centre panel structure 18, 20, and maintaining the integrity of the can end until a substantial degree of doming of the centre panel 18 has occurred (see Figures 6 and 6B, and image (c) in Figures 6A and 6C), before the can end flips inside out.

[0168] As seen in Figures 6D and 6E, a further embodiment is illustrated in which the mouth m is initially formed to be open, and the can end is constructed in such a way that the mouth m remains open, through to the stage of flipping inside out, without the opposed sides of the mouth coming into contact. It will be appreciated from comparing Figure 6D with Figures 6 and 6B that the centre panel 18 in this third embodiment does not benefit from the restraining effect of the chuck wall 14 holding back the centre panel structure 18, 20. As such, a somewhat smaller degree of doming of the centre panel 18 can be accommodated (see image (c) of Figure 6E),

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as compared with the two other embodiments (see image (c) of Figures 6A and 6C), before the can end flips inside out.

[0169] It will be understood that the can end 10 shown in Figures 2 to 5 is in the condition following initial forming of the can end from a circular blank, and that further processing steps may be performed, such as adding reinforcing structures, scoring an aperture and attaching a tab to the centre panel, or curling the peripheral cover hook to the desired shape for seaming onto the end of a can body. Similarly, a lining may be added to the can end to create a seal when it is seamed onto a can body.

[0170] With reference to Figures 7 to 12, tooling will be described which is adapted for forming the embodiment of the can end shown in Figures 2 to 6. Figures 7 to 12 all show cross-sectional views of the tooling and a circular blank 5 at various stages of being formed into the can end 10 in a plane through the tooling and can end that includes the central axis X of the can end 10, which is also the central axis of the blank 5 and a common central axis of the tooling.

[0171] Figure 7 shows an enlarged cross-sectional view of the tooling at the end of a forming step for manufacturing the can end.

[0172] The tooling includes inner tools for forming the inner side surface of the can end and outer tools for forming the outer side surface of the can end. The inner tools are arranged to be positioned on the axially inner side of a blank corresponding to the inner side of the can end, and the outer tools are arranged to be positioned on the opposite, axially outer side of the blank corresponding to the outer side of the can end.

[0173] The inner tooling includes an inner centre panel tool 60 and an inner wall tool 70. The inner wall tool 70, as shown, concentrically surrounds and is substantially adjacent to the inner centre panel tool 60, such that a radially outer wall 68 of the inner centre panel tool 60 is adjacent a radially inner wall 72 of the inner wall tool 70. As will be discussed in more detail below, the radially inner wall 72 of the inner wall tool 70 beneficially cooperates with features of the inner centre panel tool 60 in the forming of a blank 5 into a can end 10.

[0174] The outer tooling includes an outer centre panel tool 80, an outer chuck wall tool 90 and an outer seam tool 100. The outer tools are concentrically arranged,

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with the outer chuck wall tool 90 surrounding and substantially adjacent to the outer centre panel tool 80, such that a radially outer wall 86 of the outer centre panel tool 80 is adjacent a radially inner wall 94 of the outer chuck wall tool 90, and with the outer seam tool 100 surrounding and substantially adjacent to the outer chuck wall tool 90, such that a radially outer wall 96 of the outer seam tool 100 is adjacent a radially inner wall 104 of the outer seam tool 100.

[0175] The inner tools and outer tools are also arranged concentrically with respect to one another, about a central axis corresponding to the central axis X of a can end which the tooling is for forming (as well as that of the circular blank 5 to be formed into the can end 10 by the tooling).

[0176] The tools are arranged such that the inner tools can move axially relative to one another, and so that the outer tools can move axially relative to one another. Similarly, the inner tools are able to move axially relative to the outer tools. Movement of the outer tools relative to the inner tools is restricted by the inner and outer tools being opposed to one another. In particular, the inner centre panel tool 60 is opposed to the outer centre panel tool 80, whilst the inner wall tool 70 is opposed to the outer chuck wall tool 90 and the outer seam tool 100. Outer chuck wall tool 90 and outer seam tool 100 are thus also considered as being outer wall tools.

[0177] As shown in Figure 8, the outer centre panel tool 80 has an outer diameter at its radially outer wall 86 that is less than the inner diameter at the radially inner wall 72 of the inner wall tool 70, and, similarly, less than the outer diameter at the radially outer wall 68 of the inner centre panel tool 60. As such, the outer centre panel tool 80 may move axially to become at least partially disposed within said inner wall tool 70, leaving an annular gap G between the radially inner wall 72 of the inner wall tool 70 and the radially outer wall 86 of the outer centre panel tool 80.

[0178] A radially inner portion of the outer chuck wall tool 90 is arranged to extend across the annular gap G on the outer side of the tooling, whilst a radially outer peripheral portion of the inner centre panel tool 60 is arranged to extend across the gap G on the inner side of the tooling, these portions of the two tools thus also being opposed to one another in this region. In operation of the tooling, the opposed inner and outer centre panel tools 60 and 80 move together relative to the opposed inner and outer wall tools 70, 90 and 100, in order to effect axial compression of the portion

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7 of the blank 5 between the opposed radially inner portion of the outer chuck wall tool 90 and the radially outer peripheral portion of the inner centre panel tool 60 opposed thereto.

[0179] In particular, the tooling is configured to form the panel wall 20, annular bead 16 and curved transition 50 of can end 10 by axially compressing an axially extending portion 7 of a blank 5 which extends across the annular gap G between the upper and lower tools.

[0180] An important component of the tooling is the inner centre panel tool 60. The inner centre panel tool 60 has an axially outwardly facing surface that is configured to promote the formation of the panel wall and annular bead structures of the can end 10. The external shape of the inner centre panel tool 60 substantially corresponds to the shape of the axially inwardly facing portions of centre panel 18, the panel wall 20 and the annular bead 16 of the inner surface of the can end 10.

[0181] In the example here, inner centre panel tool 60 has a central panel region 62 that is substantially flat. A sloping peripheral wall 64 extends radially outwardly and axially inwardly from the edge of the central panel region 62. In the cross-sectional plane including the central axis of the tooling, the radially outer edge of the sloping peripheral wall 64 terminates in an axially outward peak 67, so as to form a concave annular recess 66 facing in the axially outward direction. The concave annular recess 66 corresponds with, and is arranged to promote formation of, the annular bead 16. The concave annular recess, in particular, faces the gap G formed between the outer centre panel tool 80 and the inner wall tool 70.

[0182] A feature of the inner centre panel tool 60 is that the central panel region 62 smoothly blends at its outer periphery with the sloping peripheral wall 64. The sloping peripheral wall 64 is shaped so as to curve gradually axially inwardly away from the central panel 62 region in the radially outward direction. In the example shown, the curved sloping peripheral wall blends smoothly at its radially inner end with the central panel region 62 and at its radially outer end into the concave annular recess 66.

[0183] The gradual curvature of the sloping peripheral wall, away from the central panel region, serves to encourage the axially extending portion 7 of a blank 5 which is axially compressed against the inner centre panel tool 60 to roll out onto the

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sloping peripheral surface 64 from the central panel region 62 in a radially outward direction, so that the inner surface of the blank will adopt the shape of the axially outward surface of the inner centre panel tool 60. In the example shown, the sloping peripheral wall 64 has a substantially constant curvature, although it is contemplated that the sloping peripheral wall 64 may include straight sections which are nevertheless sloped axially inwardly and radially outwardly.

[0184] The concave annular recess 66 is also shown as being of substantially constant curvature, and having a radius of curvature which is substantially smaller than the radius of curvature of the convex portion of sloping peripheral wall 64. This concave annular recess 66 allows part of the intermediate annular portion 7 of a blank 5 which is being axially compressed to roll or curl up within the recess during the axial compression process, to produce the tightly rolled annular bead 16. This rolling of the annular bead also serves to draw the blank material in the central panel region 6 radially outwardly, so as to bring the central panel region 6 into tension as the blank 5 being formed is pressed against the inner centre panel tool 60 and the annular bead 16 is rolled tight in the annular recess 66.

[0185] The lower centre panel tool 60 is beneficially arranged to cooperate with the radially inner wall 72 of the inner wall tool 70. As can be seen in Figure 7, the axially outward annular peak 7 at the peripheral edge of the sloping peripheral wall 64 provides a relatively smooth transition between the concave annular recess 66 and the radially inner wall 72 of the inner wall tool 70. The radially inner wall 72 of the lower wall tool 70 thus acts to inhibit radially outward deflection of the axially extending portion 7 of the blank 5 as it is compressed in the annular gap G. This in turn helps to urge the material to form into a roll in the annular recess 66, and to cause the material to become more tightly rolled as the axial compression proceeds further.

[0186] The sloping peripheral wall 64 and the concave annular recess 66 of the inner centre panel tool, together with the radially inner wall 72 of the inner wall tool 70, define an annular recess R. Annular recess R is concave, facing in the axially outward direction, and is recessed relative to the substantially flat central panel region 62 of the inner centre panel tool 60. Annular recess R substantially opposes the annular gap G between the outer centre panel tool 80 and the inner wall tool 70.

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[0187] The outer centre panel tool 80 has an outer diameter at the radially outer wall 86 which is larger than the diameter of the flat central panel region 62 of the inner centre panel tool 60. In the example shown, a central panel region 82 of the outer centre panel tool 80 is also slightly larger than the central panel region 62 of the inner centre panel tool 60. The outer centre panel tool 80 also exhibits a sloping peripheral wall 84, extending from the central panel region 82 to the radially outer wall 86 in the axially- and radially-outward direction. The sloping peripheral wall 84 is preferably curved to extend gradually axially outwardly from the central panel region 84 in the radially outward direction. As shown, the sloping peripheral wall 84 may be continuously curved so as to blend at one end with the central panel region 82 and at the other end with the radially outer wall 86. The sloping peripheral wall 84 may have a constant radius of curvature.

[0188] As can be seen in Figure 8, the sloping peripheral wall 84 has an important function in allowing the circular blank 5 to be axially drawn to form an intermediate annular portion 7 which extends axially- and radially-outwardly from the centre panel region 6 of the blank 5. It is this axially drawn, intermediate annular portion 7 which is subsequently axially compressed to form the panel wall 20, annular bead 16 and curved transition 50. In the axial drawing process, the curvature of the sloping peripheral wall 84 allows the circular blank to be drawn around the outer centre panel tool 80 without being bent around a sharp corner that could damage coatings on the blank material or cause stress concentrations that result in drawing defects.

[0189] By having a diameter larger than that of the central panel region 62 of the inner centre panel tool 60, the outer centre panel tool 80 also causes the drawn, axially extending, intermediate annular portion 7 to be formed with a radially-outward curve that promotes initial deformation of the intermediate annular portion at a point near to the peripheral edge of the centre panel region 6. Consequently, when the intermediate annular portion 7 is subsequently axially compressed against the inner centre panel tool 60, it will tend to deform radially outwardly from the point of the radially outward curve formed by the sloping peripheral wall 84 of the outer centre panel tool 80. This promotes the blank material in the radially innermost portion 7a of the intermediate annular portion 7 to roll radially outwardly along the outer surface of the inner centre panel tool 60 when the blank is first axially compressed, and so for that radially innermost portion 7a to adopt the shape of the sloping peripheral wall 64.

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[0190] As mentioned above, the inner wall tool 70 opposes the outer wall tools, including the outer chuck wall tool 90 and the outer seam tool 100.

[0191] In order to form a sloping chuck wall 14, the outer chuck wall tool 90 includes an axially inwardly facing chuck wall surface 92 which is angled axially- and radially-outwardly. The inner wall tool 70 similarly includes an axially outwardly facing surface including a radially inner portion formed as a chuck wall surface 74 and angled axially- and radially-outwardly in the same way as the outer chuck wall tool. The chuck wall surface 74 of the inner wall tool 70 opposes the chuck wall surface 92 of the outer chuck wall tool 90, and these surfaces clamp part of an outermost portion 8 of the circular blank 5 to form the chuck wall 14 during drawing and reforming of the blank 5.

[0192] In a similar manner, in order to form a seaming panel 26, the outer seam tool 100 includes an axially-inwardly facing seaming panel surface 102 which extends radially-outwardly and is slightly concavely curved facing in the axially inward direction. The axially outwardly facing surface of the inner wall tool 70 similarly includes a radially outer portion formed as a seaming panel surface 76 which extends radially-outwardly in the same way as the seaming panel surface 102 of the outer seam tool 100, and which is slightly convexly curved in the axially outward direction, to match the concave curvature of the seaming panel wall 102 of the outer seam tool 100. The seaming panel surface 76 of the inner wall tool 70 opposes the seaming panel surface 102 of the outer seam tool 100, and these surfaces clamp part a radially outer portion of the outermost portion 8 of the circular blank 5 to form the seaming panel 26 during drawing and reforming of the blank 5.

[0193] It will be appreciated that the tooling is configured to form the panel wall 20, annular bead 16, and the curved connection portion 50 with only a single axial movement of the opposed inner and outer wall tools 70, 90 and 100 in an axially inward direction relative to the opposed inner and outer centre panel tools 60 and 80.

[0194] Figures 9 to 11 show cross-sectional views of the tooling at several different axial positions during the forming of can end 10 by axial compression of the blank 5. Figures 9A to 11A show enlarged views of the circled parts, respectively, of Figures 9 to 11.

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[0195] The circular blank may be considered as nominally including three regions, a centre panel region 6 corresponding to the central panel region 62 of the inner centre panel tool, an intermediate annular portion 7 which extends radially outwardly from the peripheral edge of the centre panel region 6 across the annular gap G, and an outermost peripheral portion 8, being the portion of the blank 5 extending radially outwardly of the radially inner edge 72 of the inner wall tool 70. These regions are thus defined with respect to the tooling, and it will be appreciated that the particular material of the blank 5 in each region may change during the processing of the blank, due to material flow from one region to the next as the blank 5 is drawn and reformed.

[0196] In Figure 9, the opposed inner and outer wall tools 70, 90 and 100 clamp an outermost peripheral portion 8 of the blank 5, whilst opposed inner and outer centre panel tools 60 and 80 clamp a centre panel region 6 of the blank 5. Intermediate annular portion 7 of the blank 5 is unclamped, and extends across the annular gap G. In the view shown in Figure 9, the opposed inner and outer wall tools 70, 90 and 100 have been moved axially outwardly relative to the opposed inner and outer centre panel tools 60 and 80, so as to axially draw the blank 5 to form axially extending intermediate annular portion 7, which extends radially- and axially-outwardly from the centre panel region 5 across the annular gap G.

[0197] In Figure 10, the opposed inner and outer wall tools 70, 90 and 100 have been moved axially inwardly relative to the opposed inner and outer centre panel tools 60 and 80 in order to reform the intermediate annular portion 7 by axially compressing it. The intermediate portion 7 has deformed radially outwardly from the radially outward curve formed by the sloping peripheral wall 84 of the outer centre panel tool 80, and the inner portion 7a of the intermediate annular portion 7 has been forced against and rolled around the sloping peripheral wall to adopt the shape of the peripheral annular wall, including the concave annular recess 66. The radially inner portion 7a thus lies in the annular recess R opposed to the annular gap G.

[0198] Reforming the intermediate portion 7a in this way brings the material of the blank in the centre panel region and/or in the panel wall into tension, as it is effectively "stretched" over the peripheral forming surface of the inner centre panel tool 60. Accompanying material flow across the centre panel region 6, as the blank is axially compressed against the inner centre panel tool 60, is shown schematically with arrows in Figure 12.

[0199] The radially outer end of the radially inner portion 7a is pressed against and constrained by the radially inner wall 72 of the inner wall tool 70. The remaining portion 7b of the intermediate annular portion 7 is axially compressed and has bent radially inwardly due to the bending stresses created in the material to form a radially inward curve. The upper part of the radially inward curve comes into contact with, and is constrained and supported by, the axially inwardly facing chuck wall surface 92 of the outer chuck wall tool 90.

[0200] In Figure 11, the opposed inner and outer wall tools 70, 90 and 100 have been moved further axially inwardly relative to the opposed inner and outer centre panel tools 60 and 80 in order to further reform the intermediate annular portion 7 by further axially compressing it. The remaining portion 7b of the intermediate annular portion 7 further curves and deforms radially inwardly from the radially inward curve. The upper part of the remaining portion 7b has rolled against the portion of the chuck wall surface 92 of the outer chuck wall tool 90 which extends across the annular gap G to conform to the shape of the chuck wall surface 92, thus forming a radially inner portion of the chuck wall 14.

[0201] The further axial compression has caused the radially inward curve in the remaining portion 7b to tighten, forming the curved transition 50. As the curved transition is pressed axially inwardly by the chuck wall surface 92, the radially inward curve tightens and forms the curved transition, and at the same time forces the blank material into the concave annular recess 66 of the inner centre panel tool 60 to cause it to roll up tightly to form the annular bead 16. This tightening of the bead causes it to roll up in the concave annular recess 66.

[0202] Figures 13 to 17 again show enlarged cross-sectional views of the tooling at several different axial positions during the forming of can end 10 by axial compression of the blank 5. A method of forming the can end 10 will be described with reference to these Figures.

[0203] A preliminary step in the method involves axially drawing the circular blank 5 by drawing an outermost peripheral portion 8 of the blank 5 in an axially outward direction relative to a centre panel region 6 of the blank, to create an intermediate annular portion 7 extending radially- and axially-outwardly from the peripheral edge of the centre panel region 6. The drawn intermediate annular portion 7, as shown in Figure 13, extends predominantly axially outwardly between the centre panel region

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6 and the outermost peripheral portion 8, which are respectively clamped to facilitate the axial drawing. The axial drawing process is arranged so as to impart a preliminary radially outward curve into the intermediate annular portion 7 substantially adjacent to the peripheral edge of the centre panel region 6.

[0204] As can be appreciated from Figure 13, when the drawn intermediate annular portion 7 is subsequently axially compressed, the compressive forces will be transmitted along the substantially straight-walled section of the intermediate annular portion 7, and will tend to push the radially outward curve to deform it axially inwardly onto the sloping peripheral wall 64 which is part of the axially outer forming surface of inner centre panel tool 60. This will tend to cause the radially innermost part 7a of the intermediate annular portion to roll radially outwardly onto the sloping peripheral wall 64 from the peripheral edge of the centre panel region 6. At the same time, compressive forces acting at the opposite end of the intermediate annular portion 7 are resisted by the outermost peripheral portion 8 being clamped, and in particular by the radially- and axially-inward slope of a clamped chuck wall portion of the outermost peripheral portion 8 being less susceptible to deformation than the radially outward curve near the centre panel region 6.

[0205] Figures 14 to 17 show progressive stages of the axial compression process by which the drawn intermediate annular portion 7 is then reformed.

[0206] As seen in Figure 14, when the outermost peripheral portion 8 is moved axially inwardly relative to the centre panel region 6, the radially inner portion 7a of the intermediate annular portion 7 rolls radially outwardly and axially inwardly onto the forming surface of the inner centre panel tool 60 and substantially adopts the shape of the sloping peripheral wall 64, including the concave annular recess 66.

[0207] As further radially outward rolling of the radially outward curve is constrained by the radially inner wall 72 of the inner wall tool 70, and also as a result of the shape of the concave annular recess 66 which terminates in the axially outward peak 67 at its radially outer edge, the intermediate annular portion 7 cannot be rolled further radially outwardly. Adopting the shape of the concave annular recess 66, bending moments are induced in the radially inner portion 7a of the intermediate annular portion 7, which in turn form a radially inward curve in the remaining portion 7b of the intermediate annular portion 7. This causes the remaining portion 7b, which otherwise extends predominantly axially, to bow radially inwardly at around the centre, in the axial direction, of the remaining portion 7b.

[0208] With reference to Figures 15 and 16, further axial compression, by further moving the outermost peripheral portion 8 axially inwardly relative to the centre panel region 6, the initial radially inward curve progressively collapses further radially inwardly at the axial centre of the remaining portion 7b. The upper end of the remaining portion 7b then rolls radially outwardly onto, and is pressed axially inwardly by, a radially- and axially-inwardly sloped forming surface, here provided by the chuck wall surface 92 of the outer chuck wall tool 90 extending across the annular gap G.

[0209] At the same time, the axially inward deformation of the radially inward curve causes the lower end of remaining portion 7b to force the curved portion of the radially inner portion 7a of the intermediate annular portion 7 which has been formed in the concave annular recess 66 to roll up. This causes the annular bead 16 to be formed as a tightly rolled, continuously curved bead. The bead may exhibit a substantially constant curvature defined by the radius of curvature of the concave annular recess 66.

[0210] The further axial compression, together with the rolling of the material in the concave annular recess 66, also causes the radially inward curve to tighten into a curve with reduced radius of curvature, forming the curved transition 50.

[0211] As shown in Figure 17, final axial compression by moving the outermost peripheral portion 8 axially inwardly relative to the centre panel region 6 tightens the annular bead 16 and curved transition 50 to their final radii of curvature, without axially collapsing these bead structures. The axial compression is preferably terminated at a point before the radially inward curve comes into contact with the radially inner portion 7a of the intermediate annular portion 7, so that an open mouth m is formed between the curved transition 50 and the panel wall 20 of the formed can end 10. Alternatively, the axial compression may continue until these surfaces are brought into contact, with the mouth m closed.

[0212] As will be apparent, all of the axial compression illustrated, from the position in Figure 14 to that in Figure 17, is achieved by a single axial motion of moving the outermost peripheral portion 8 of the blank 5 axially inwardly relative to

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the centre panel region 6, so as to reform the axially drawn intermediate annular portion 7 in a single operation.

[0213] It is also to be noted that, as a reform process is used to form the annular bead 16 and the curved transition 50, these can be formed from a blank of relatively thin material to have very small inner radii, which would not be possible with conventional press tooling. In particular, where the inner radii of pressed components are very small, the tools required to form them cannot be used without damaging the material of the blank. By contrast, the reform method used in the method above allows a tightly rolled annular bead and adjacent curved transition to be formed from a thin blank without damage.

[0214] The can end 10 is formed upon completion of this operation, although as noted above further processing steps may be carried out on the can end.

[0215] Turning to Figure 18, there is shown an enlarged view, similar to Figure 4A, of the bead and chuck wall portion of another embodiment of a can end according to the present invention, where side walls defining the bead mouth are parallel.

[0216] Specifically, all features of the can end are the same as described above for the can end of Figures 2 to 5, except that the sides of the bead mouth do not converge, and straight-walled sections 40 and 49, respectively, connect the curved panel wall 20 and curved transition 50 to each end 44 and 48 of the bead wall 46.

[0217] Nevertheless, the centre panel structure retains a substantially outwardly domed shape, and the bead 16 extends radially outwardly of the inner peripheral edge of the chuck wall structure.

[0218] Figure 19 shows an enlarged view, similar to Figure 4A, of the bead and chuck wall portion of a further embodiment of a can end according to the present invention, where the side walls defining the bead mouth diverge.

[0219] In this example, again, a straight walled section 40 is provided in the panel wall, between curved panel wall 20 and the inner end 44 of the bead wall 46. On the outer side of the bead 16, the outer end 48 of the bead wall 46 connects directly to the curved transition region 50 at a point of inflexion. The straight wall section 40

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and the curved transition 50 are divergent from the bead 16 towards the outside of the can end.

[0220] At the same time, the centre panel structure retains a substantially outwardly domed shape, and the bead 16 extends radially outwardly of the inner peripheral edge of the chuck wall structure.

[0221] Figure 20 shows an enlarged view, also similar to Figure 4A, of the bead and chuck wall portion of still another embodiment of a can end according to the present invention, where the panel wall includes a substantially straight section 40 between the centre panel 18 and the bead 16. On the opposed side of the bead, the curved transition 50 and annular bead 16 are substantially the same as in the embodiment of Figures 2 to 5.

[0222] Once again, the centre panel structure retains a substantially outwardly domed shape, and the bead 16 extends radially outwardly of the inner peripheral edge of the chuck wall structure. The embodiment of Figure 20 is also likely to benefit from the straight panel wall section 40 and curved transition 50 coming into contact as the can end deflects under pressure, such that improved failure behaviour of the can end can be obtained.

[0223] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

[0224] This specification incorporates in its entirety the content and disclosure of Annex 1, which includes 69 pages of description, claims and drawings relating to the same invention, and which are incorporated herein by reference as description, claims and drawings of the present application.

[0225] Although the invention has been described with reference to specific examples it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

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CLAIMS:

1. A method of manufacturing a can end comprising:

reforming a blank by compressing an axially extending annular portion of the blank material that surrounds a central panel region of the blank to cause at least a radially inner portion of the annular portion to flow into and substantially adopt the shape of an annular recess provided on the opposite side of the central panel, in the axial direction, to the direction in which the annular portion initially axially extends; and

further reforming the blank under axial compression with at least the central panel region of the blank under tension.

2. The method of Claim 1, wherein reforming the blank includes axially compressing the annular portion against an annular tool surface extending radially outwardly from the central panel region and curving axially away from the direction in which the annular portion of the blank initially axially extends and terminating in a concave annular recess that faces back towards the direction in which the annular portion initially axially extends, such that at least the radially innermost portion of the annular portion rolls radially outwardly around the annular tool surface from the radially outer edge of the central panel region to substantially adopt the shape of said annular tool surface.

3. The method of Claim 1 or 2, wherein the annular recess includes at the radially outer edge thereof an annular concave portion facing axially outwardly and configured to promote the formation of an axially outwardly concave and radially outwardly extending bead portion.

4. The method of Claim 1, 2 or 3, wherein axially compressing the blank to cause at least the radially inner portion of the annular portion to flow into and substantially adopt the shape of the annular recess imparts a preliminary radially inward curve in a remaining portion of the annular portion that otherwise extends axially from the radially outer edge of the annular recess to an or the outermost peripheral portion of the blank that is held to facilitate said axial compression.

5. The method of Claim 4, wherein reforming the blank includes further axially compressing the blank to cause said preliminary radially inward curve in the remaining portion of the annular portion to further deform radially inwardly.

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6. The method of Claim 5, wherein further axially compressing the blank includes supporting an axially outer side of the remaining portion of the annular portion by an outer chuck wall tool, so that the axial outer end of the radially inwardly curved remaining portion is at least partially formed into at least part of a chuck wall of the end can by said further axial compression.

7. The method of any one of Claims 1 to 6, wherein all of the reforming and further reforming is performed by a single motion to progressively axially compress and reform the annular portion of the blank.

8. A method of manufacturing a can end comprising:

reforming a blank by compressing an axially extending annular portion of the blank material that surrounds a central panel region of the blank against an annular tool surface extending radially outwardly from the central panel region and curving axially away from the direction in which the annular portion of the blank initially axially extends and terminating in a concave annular recess that faces back towards the direction in which the annular portion initially axially extends, such that at least the radially innermost portion of the annular portion rolls radially outwardly around the annular tool surface from the radially outer edge of the central panel region to substantially adopt the shape of said annular tool surface.

9. The method of any one of Claims 1 to 8, further including axially drawing the blank by drawing an outermost peripheral portion of the blank in an axially outward direction relative to the central panel region of the blank in order to draw an intermediate annular portion of the blank such that it extends radially- and axially-outwardly from the central panel region to the outermost peripheral portion as said axially extending annular portion.

10. The method of Claim 9, wherein axially drawing the blank introduces a preliminary radially outward curve into the annular portion of the blank in the vicinity of the central panel region of the blank.

11. A can end manufacturing apparatus configured to manufacture a can end according to the method of any one of Claims 1 to 10.

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12. The apparatus of Claim 11 comprising:

an inner centre panel tool for pressing against the inner side of a blank in the manufacture of a can end to reform the blank against said tool, the tool comprising an axially outwardly facing central panel region and a sloped peripheral surface extending axially inwardly and radially outwardly from the central panel region and terminating at its radially outer peripheral edge in a concave annular recess facing in the axially outward direction.

13. The apparatus of Claim 12, wherein said sloped peripheral surface curves gradually axially inwardly away from the central panel region in the radially outward direction to form said slope as a domed convex annulus.

14. The apparatus of Claim 12 or 13, wherein said concave annular recess is concavely curved.

15. The apparatus of Claim 11, 12, 13 or 14, comprising tooling for manufacturing a can end to be joined to one axial end of a can body of a can for pressurized contents, the tooling comprising:

an or the inner centre panel tool for forming the inner side of a can end corresponding to the inside of the can and arranged to be disposed concentrically within an inner wall tool so as to be substantially adjacent to a radially inside wall of the inner wall tool,

wherein said inner centre panel tool has a peripheral surface sloping axially inwardly in a radially outward direction from a central panel region of the inner centre panel tool, such that said peripheral surface together with said inside wall of the inner wall tool defines an annular recess axially inwardly of the central panel region, and

wherein said annular recess is configured to promote the formation of a radially outwardly extending bead in a can end during a reform process of axially compressing a blank against the inner centre panel tool.

16. The apparatus of Claim 15, wherein said peripheral surface is sloped relative to the axial direction across at least 25% of the radial width of said annular recess extending radially outwardly from said central panel region.

17. The apparatus of Claim 15 or 16, wherein an axially outwardly facing concave annular recess is formed at the radially outer edge of the peripheral surface of the inner centre panel tool, so as, together with the inside wall of the inner wall

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tool, to promote said formation of the radially outwardly extending bead during the reform process of axially compressing a blank against the inner centre panel tool.

18. The apparatus of Claim 15, 16 or 17, wherein said peripheral surface is convexly curved gradually axially inwardly away from the central panel region in the radially outward direction to form said slope as a domed convex annulus.

19. The apparatus of Claim 11, 12, 13 or 14, comprising tooling for manufacturing a can end to be double-seamed onto one axial end of a can body of a can, the tooling comprising:

inner tools for forming the can end on a side corresponding to the inside of the can and arranged to be disposed on an axially inner side of outer tools for forming the can end on a side corresponding to the outside of the can, including:

an or the inner centre panel tool;

an inner wall tool arranged concentrically surrounding and substantially adjacent to the inner centre panel tool;

an outer centre panel tool opposed to the inner centre panel tool; and

at least one outer wall tool generally opposed to the inner wall tool and arranged concentrically surrounding and substantially adjacent to the outer centre panel tool,

wherein the opposed inner and outer wall tools are able to move axially relative to the opposed inner and outer centre panel tools,

wherein the outer centre panel tool has a smaller outside diameter than the inside diameter of a radially inner wall of the inner wall tool, the outer centre panel tool being disposable concentrically at least partially within the inner wall tool to leave an annular gap radially surrounding the outer centre panel tool, and

wherein the inner centre panel tool includes a peripheral annular surface surrounding a central panel region of the inner centre panel tool and extending axially inwardly in a radially outward direction from the central panel region, the peripheral annular surface, together with the radially inner wall of the inner wall tool, defining an annular recess extending axially inwardly from the central panel region of the inner centre panel tool, said annular recess being substantially opposed to said annular gap.

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20. The apparatus of Claim 19, wherein the peripheral annular surface terminates at its radially outer end in an annular recess configured to promote the formation of a radially outwardly extending recess during a reform process of axially compressing a blank against the inner centre panel tool.

21. The apparatus of Claim 19 or 20, wherein the at least one outer wall tool includes a chuck wall tool arranged concentrically surrounding and substantially adjacent to the outer centre panel tool and extending across the annular gap substantially opposed to the annular recess.

22. The apparatus of Claim 21, wherein the chuck wall tool includes an axially inwardly facing annular surface opposed to the annular recess, said inwardly facing surface being sloped axially outwardly in the radially outward direction.

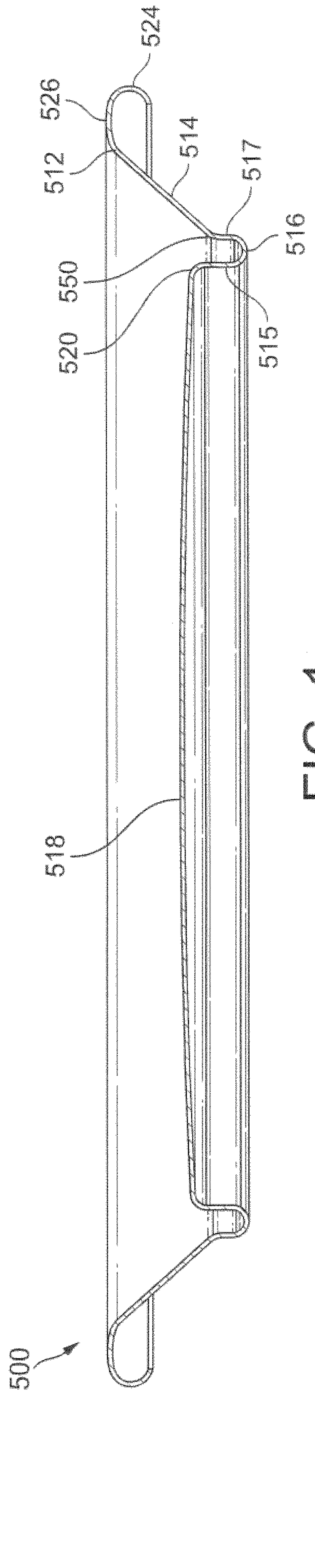
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FIG. 1

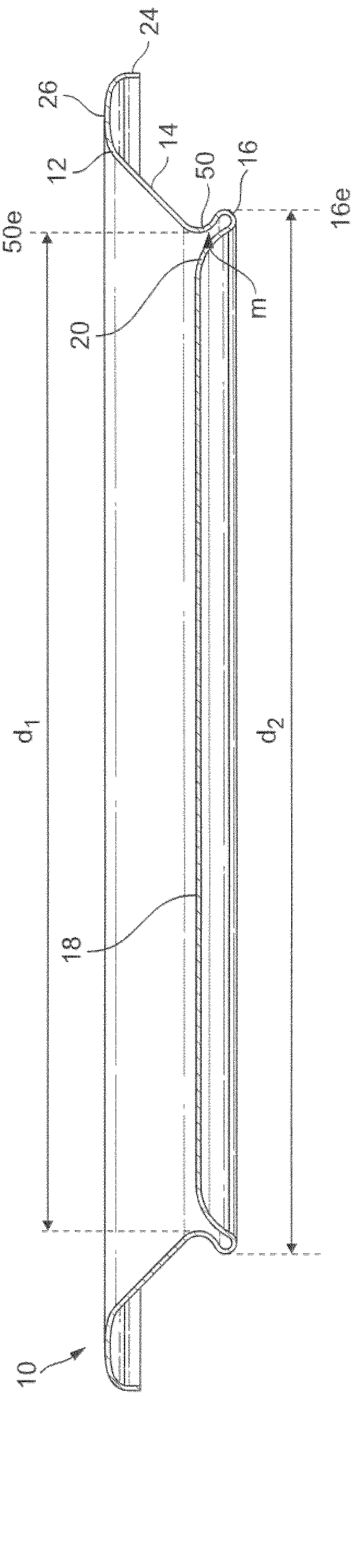
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FIG. 2

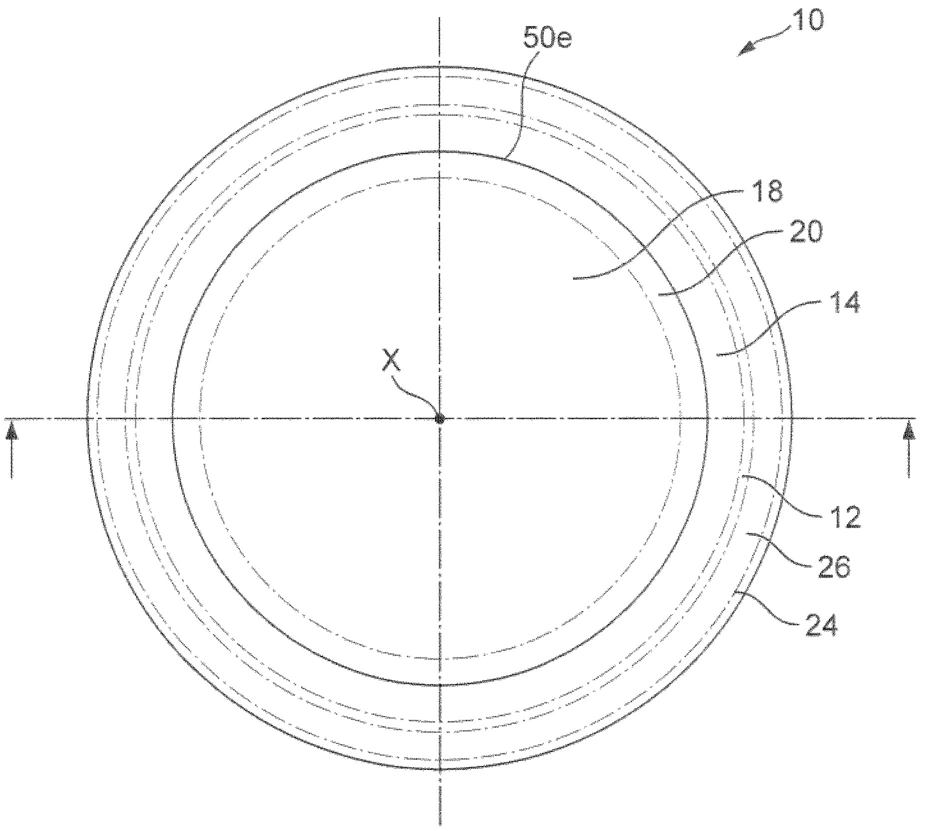

FIG. 3

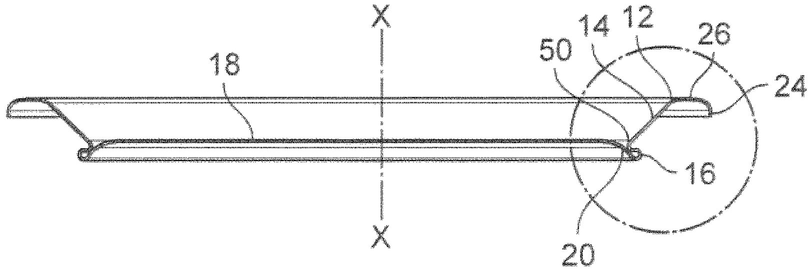

FIG. 4

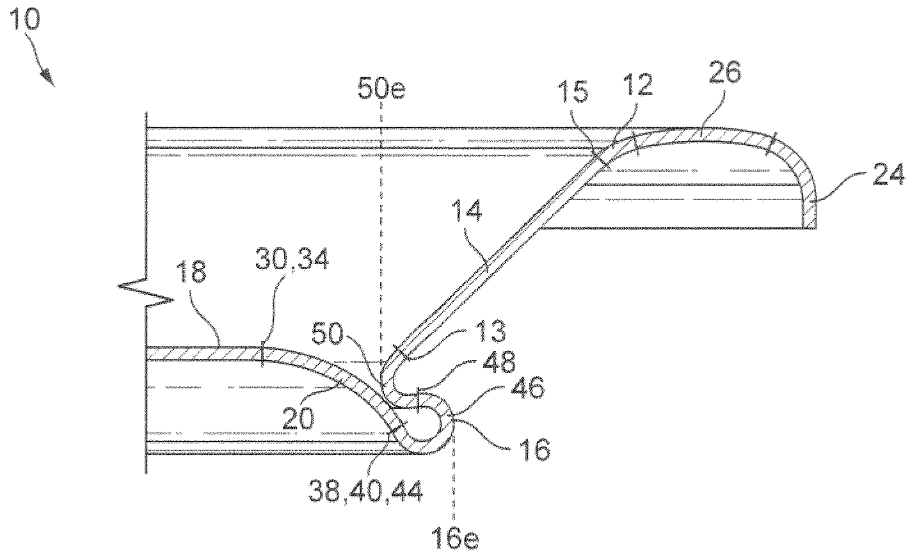
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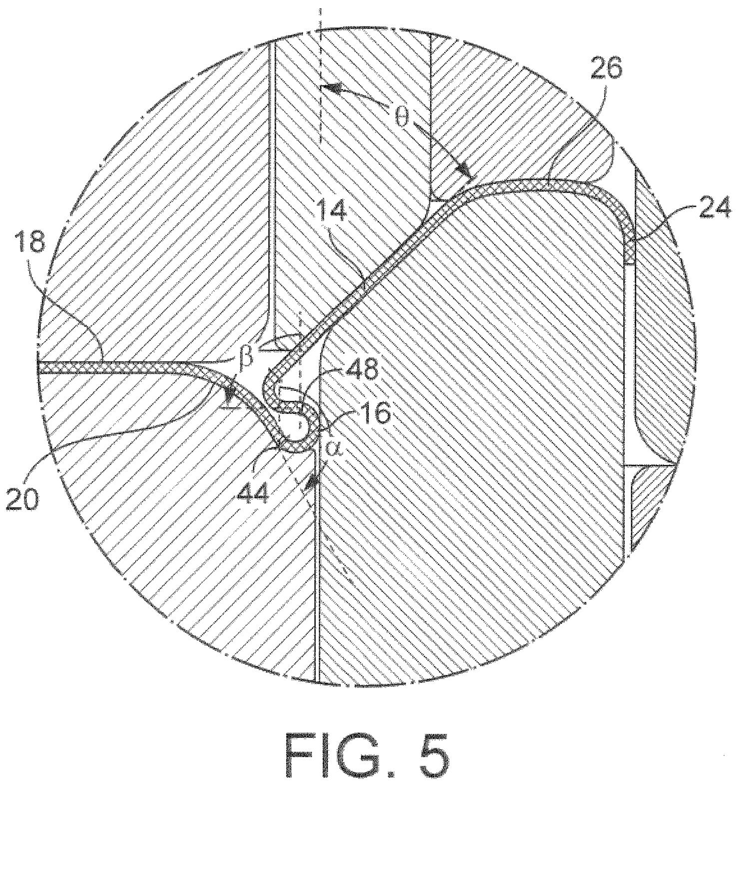
FIG. 4A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44
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FIG. 5

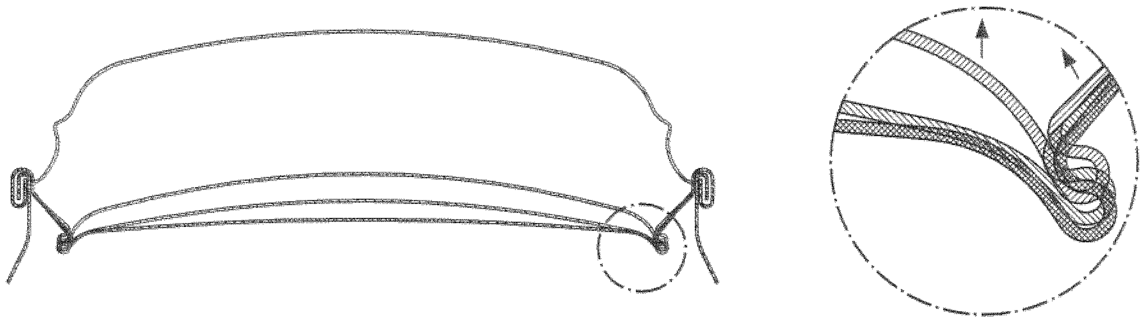
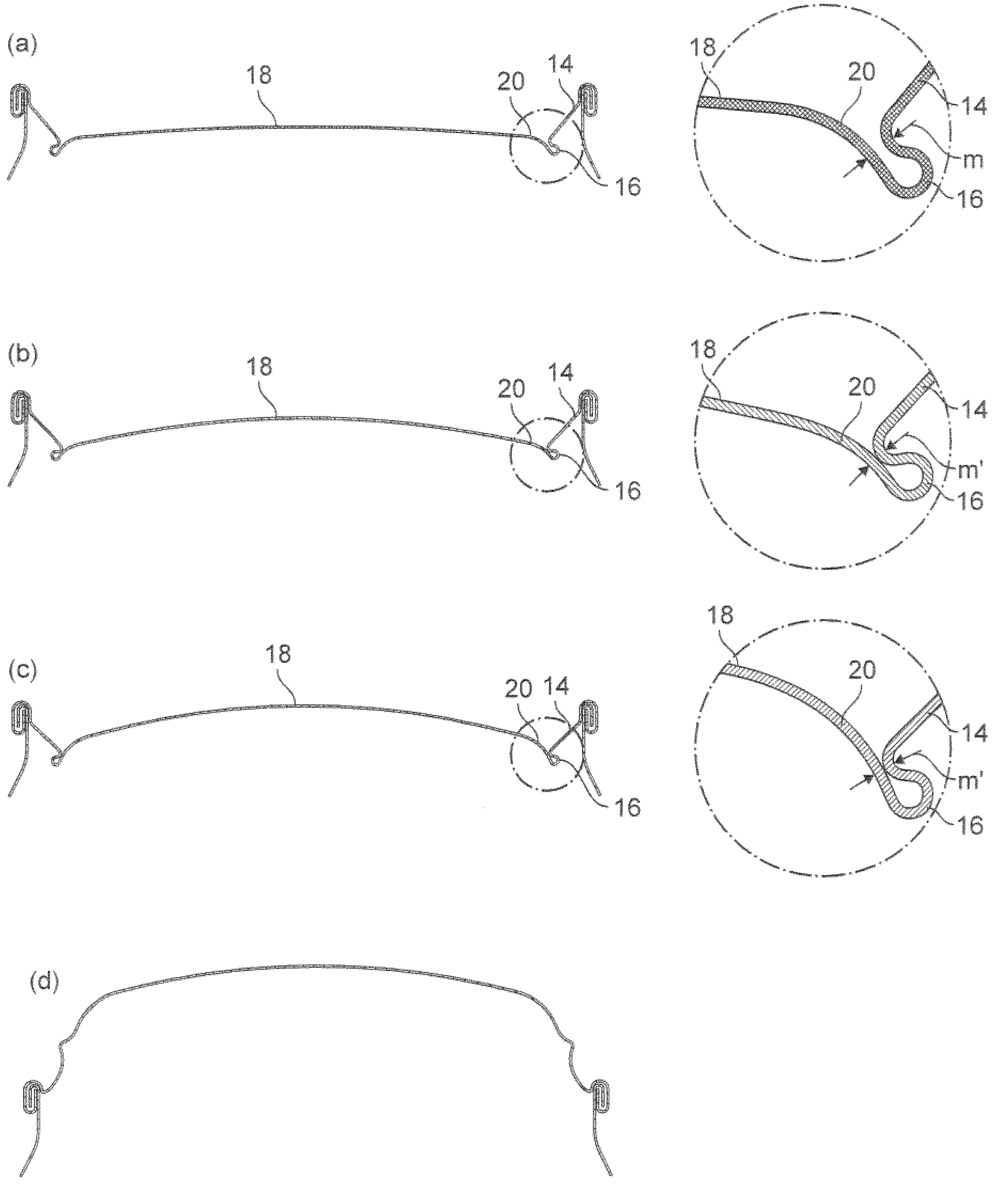


FIG. 6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m'
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(d)

FIG. 6A

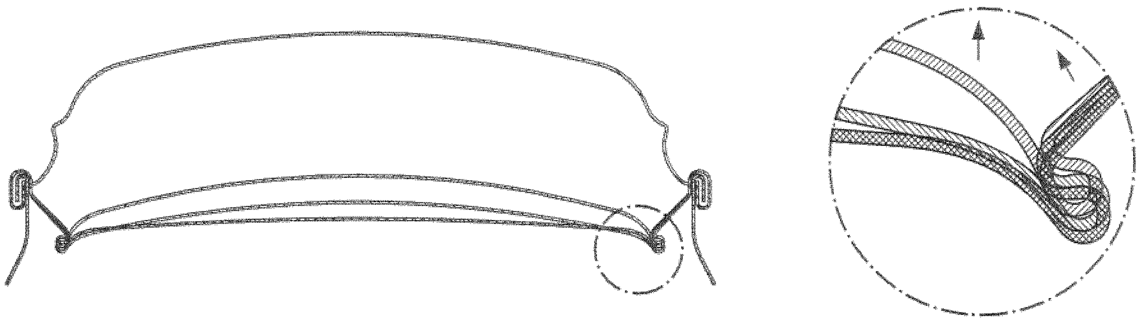
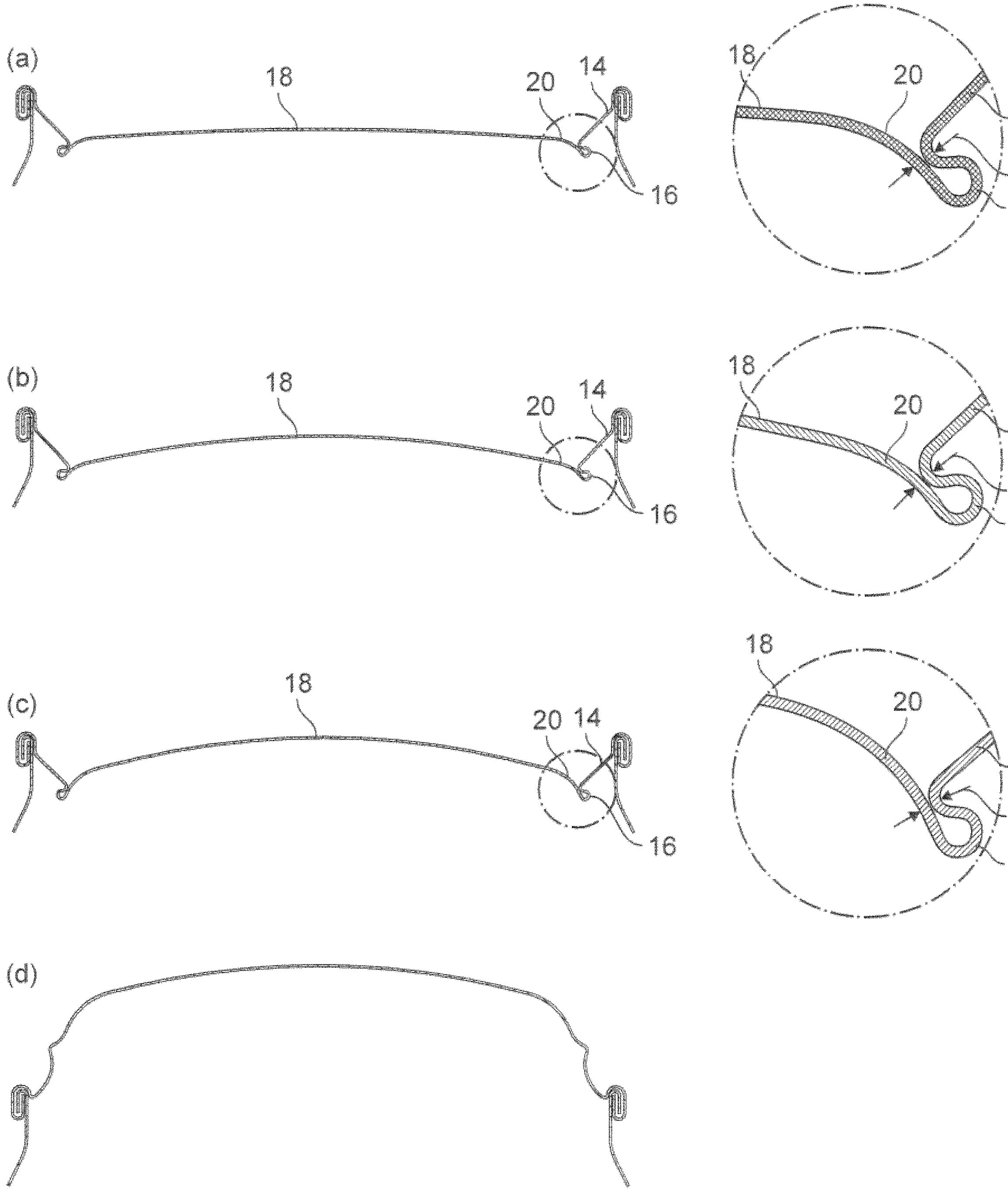


FIG. 6B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(d)

FIG. 6C

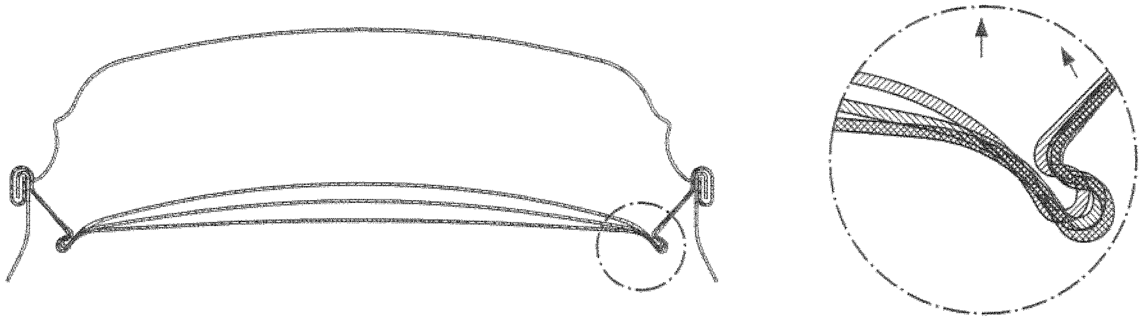
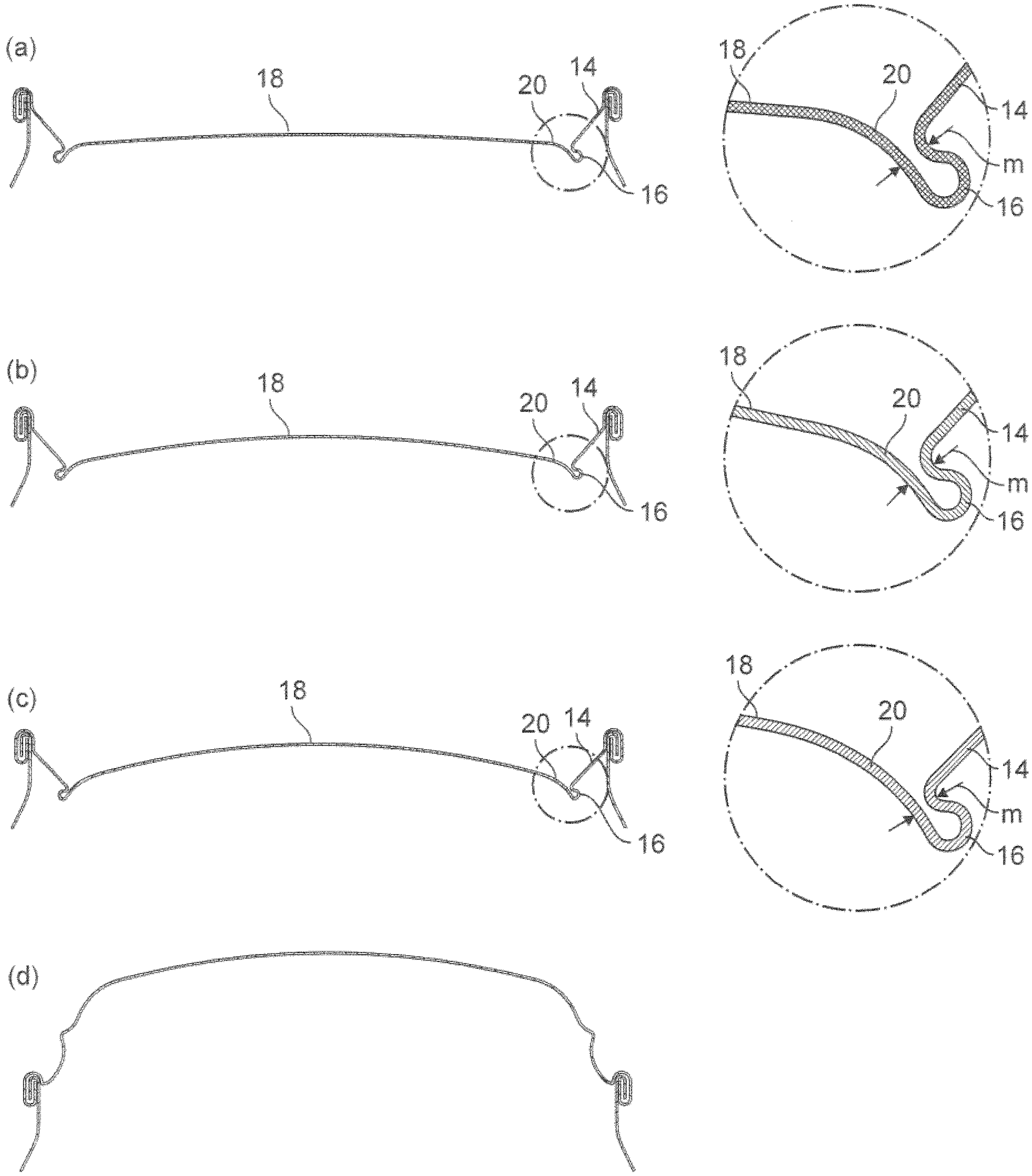


FIG. 6D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(d)

FIG. 6E

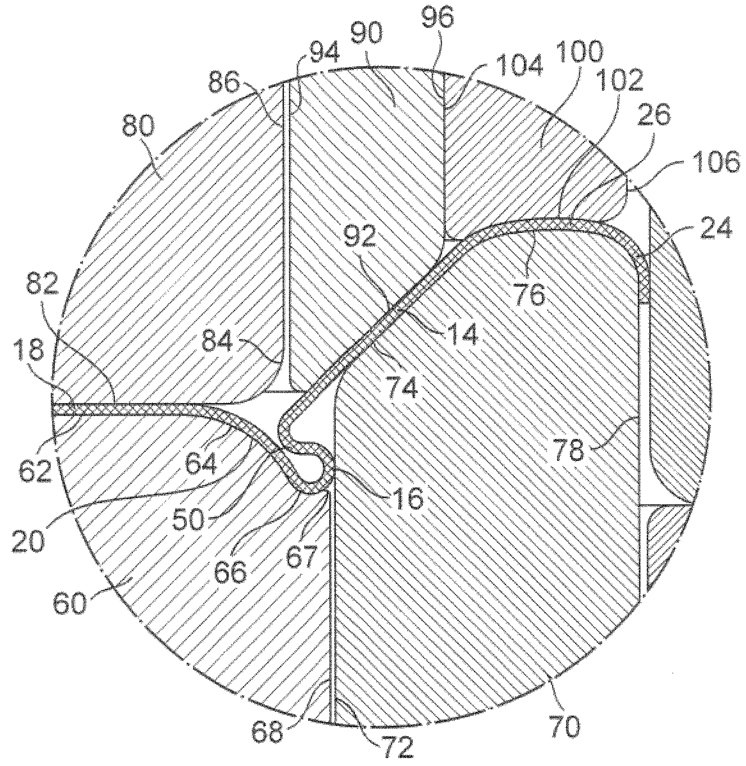
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FIG. 7

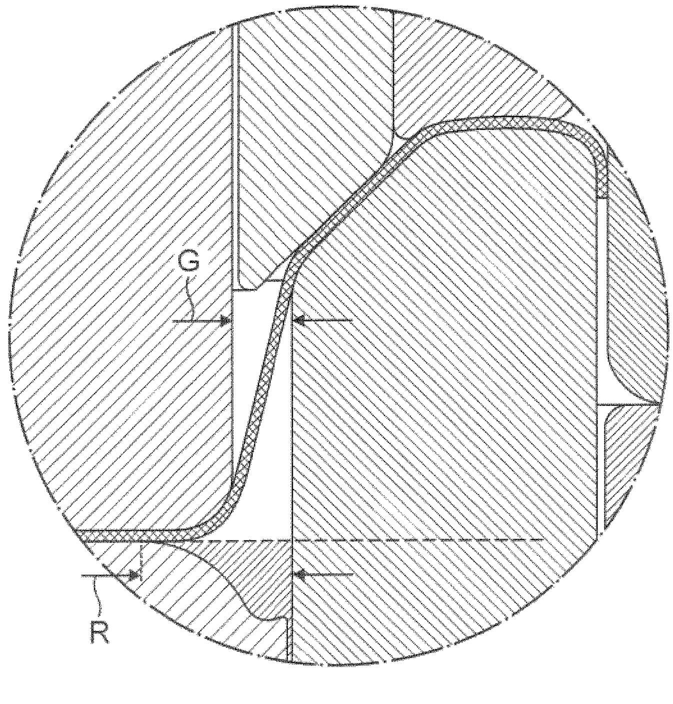
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FIG. 8

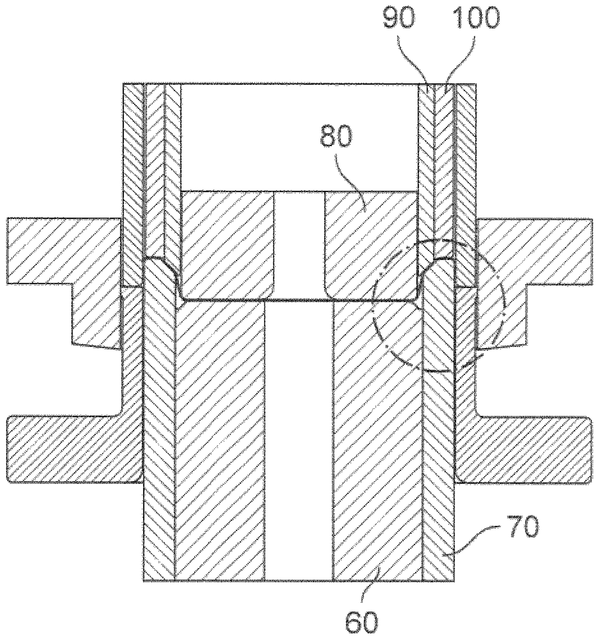

FIG. 9

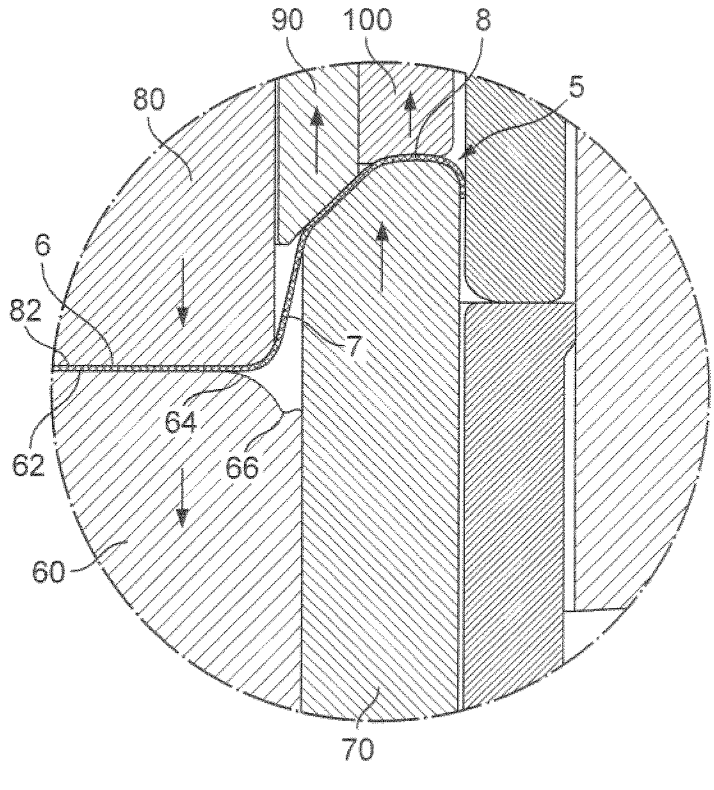

FIG. 9A

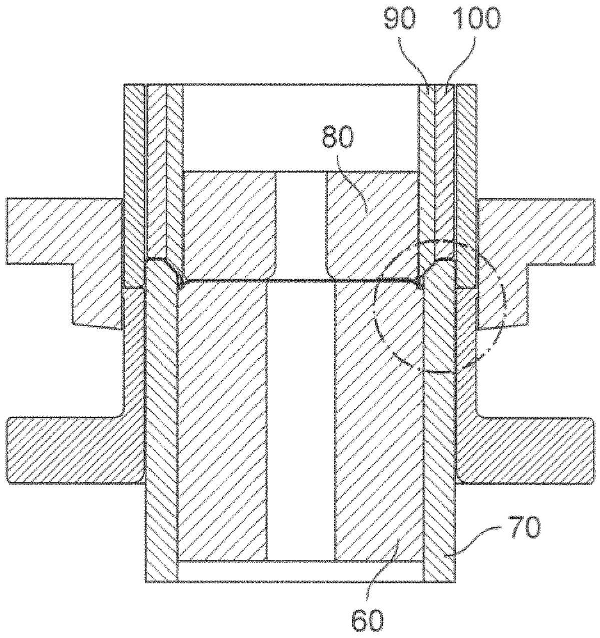

FIG. 10

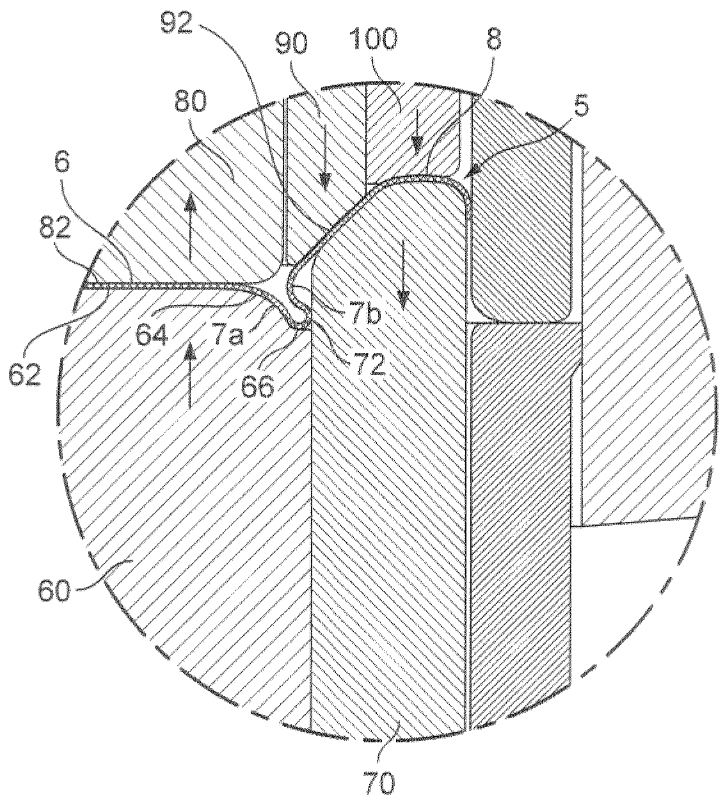

FIG. 10A

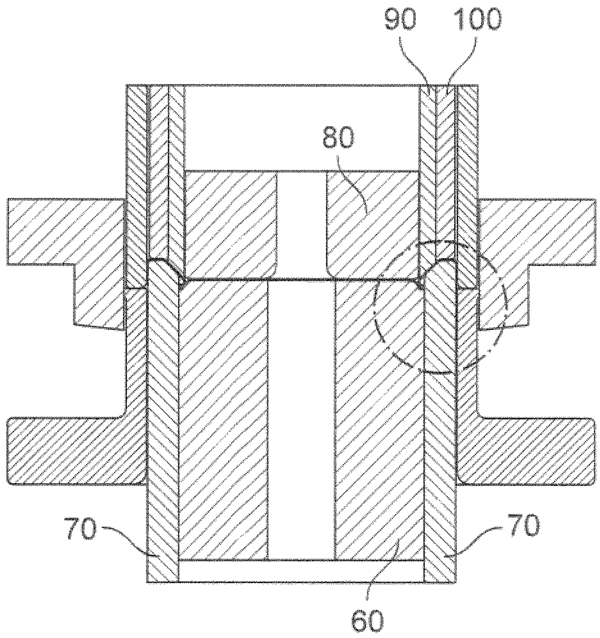

FIG. 11

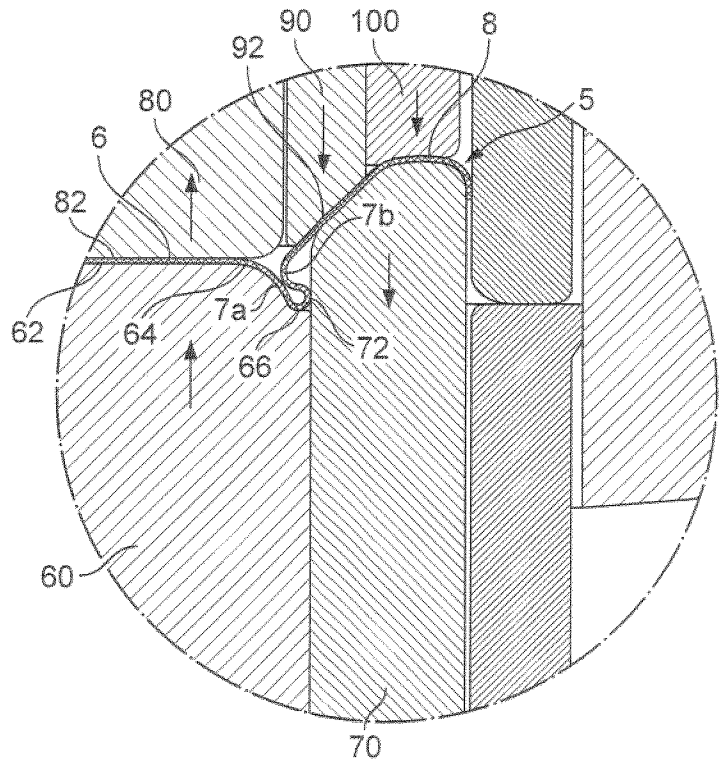

FIG. 11A

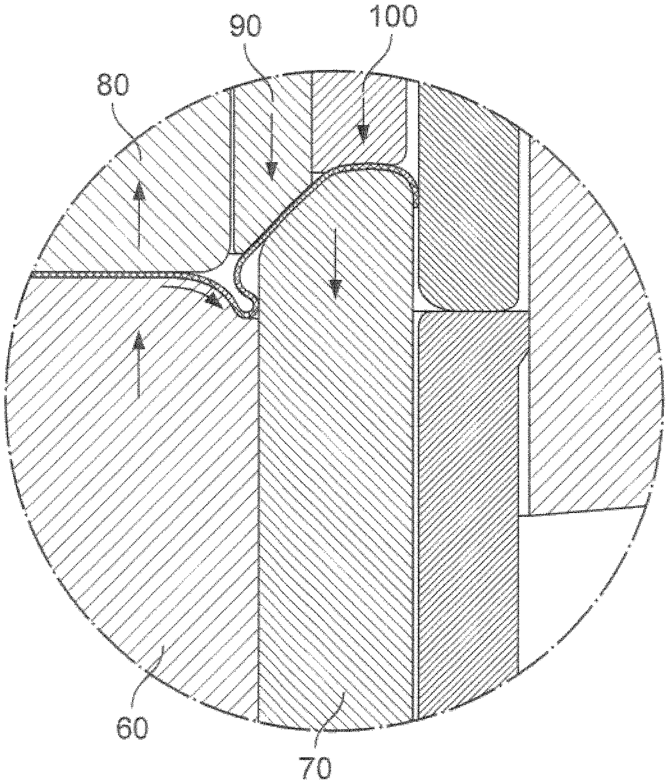
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FIG. 12

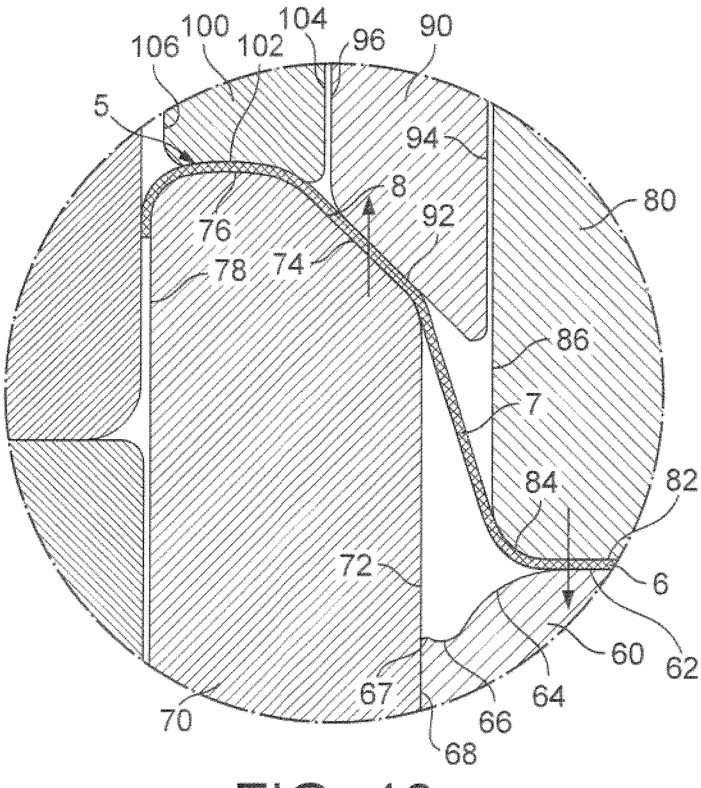
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FIG. 13

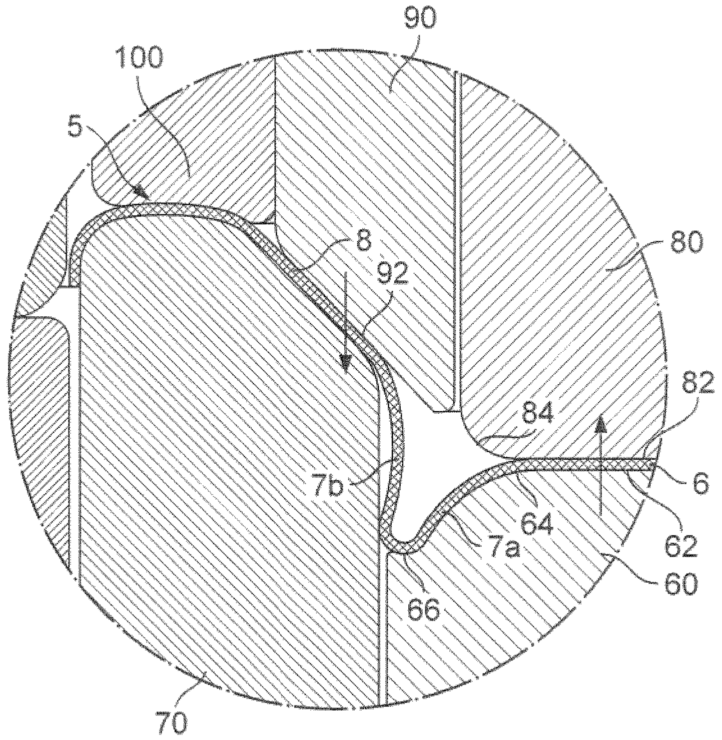
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FIG. 14

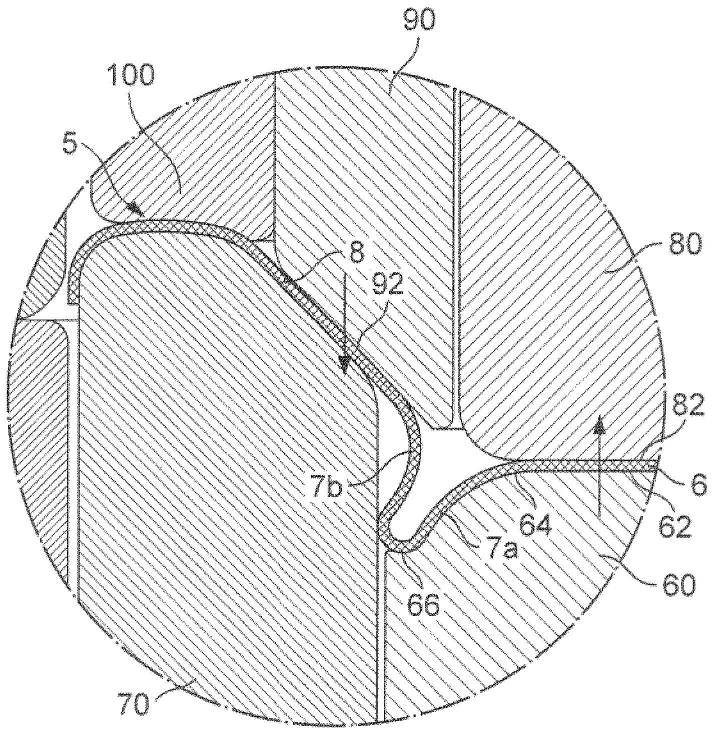
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FIG. 15

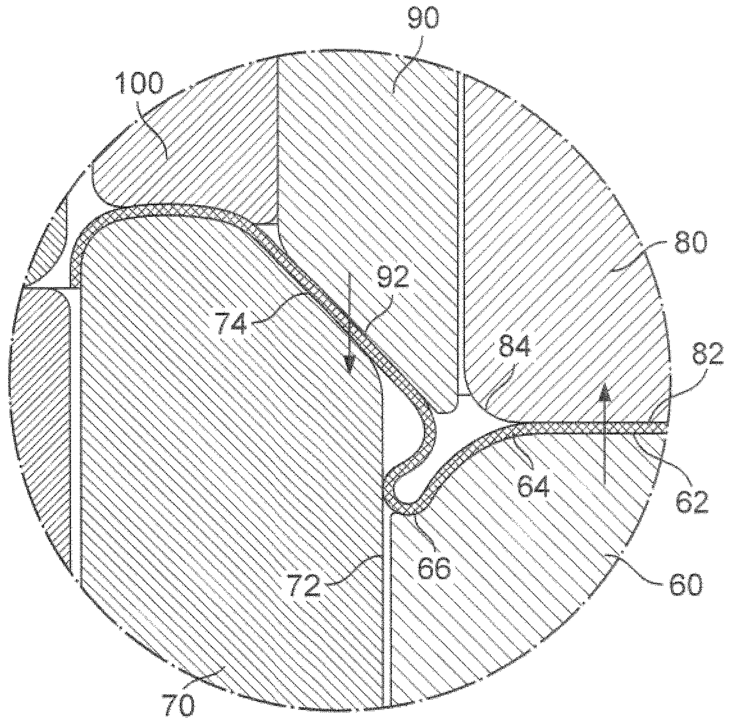
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FIG. 16

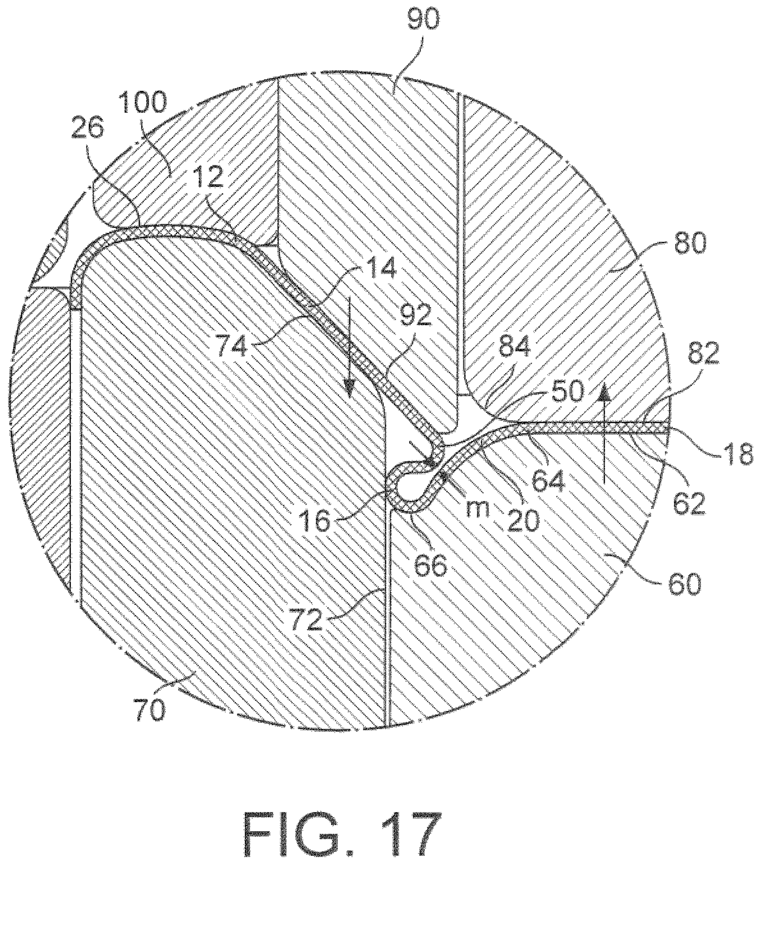
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FIG. 17

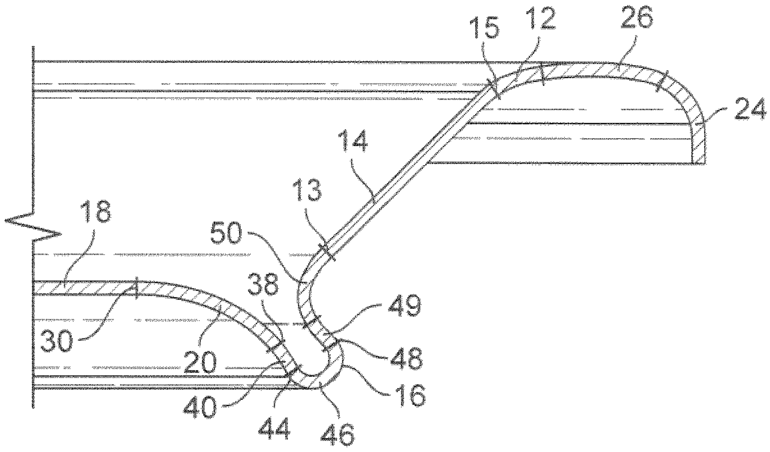
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FIG. 18

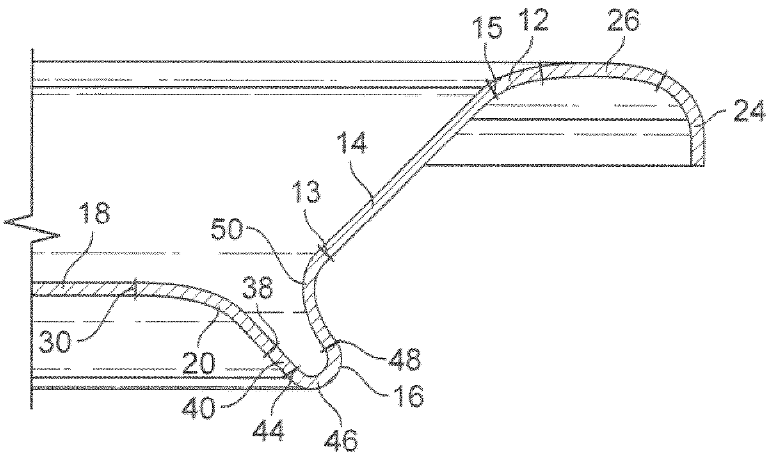
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FIG. 19

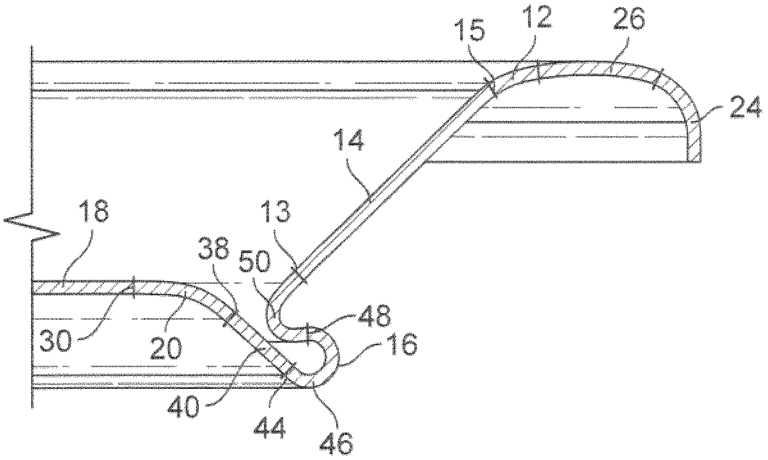
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FIG. 20

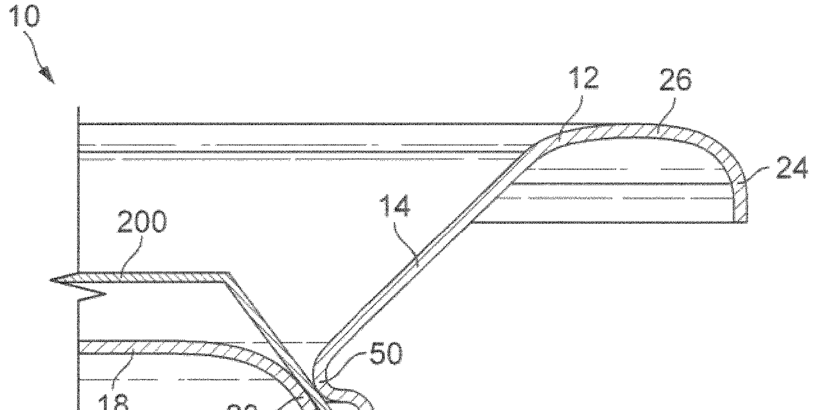
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FIG. 21