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(54) **METHOD AND APPARATUS FOR REDUCING WRINKLE FORMATION IN DEEP DRAWING**

VERFAHREN UND VORRICHTUNG ZUM REDUZIEREN VON FALTENBILDUNG BEIM TIEFZIEHEN

PROCEDE ET APPAREIL POUR REDUIRE LA FORMATION DE PLIS DANS UNE OPERATION D'EMBOUTISSAGE PROFOND

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Description

[0001] The invention relates to a method and an apparatus for deep drawing products from a blank as per the precharacterising portions of claims 1 and 8 resp.. Such a method and apparatus is known from DE-A-4038864. More in particular, the invention relates to an improved method for preventing, at least reducing wrinkle formation in the blank during deep drawing.

[0002] During deep drawing a blank between a die and a punch cooperating therewith, the edges of the blank are held by means of a downholder against a die ring cooperating with this downholder. It is important here to adjust the downholder such that a downholder force exerted on the edges of the blank is, on the one hand, sufficiently great to prevent wrinkle formation in the edges, but is, on the other hand, not greater than is necessary, because this promotes crack formation and, moreover, leads to high frictional forces between the blank and the downholder and die ring. Such frictional forces require a heavy design of the apparatus, cost unnecessarily much energy during deep drawing, lead to wear, and shorten the life of the apparatus.

[0003] In the known methods, the required downholder force is often determined by 'trial and error' during a series of experiments preceding the actual deep drawing process. The found downholder force is then multiplied by a security factor, in connection with possible variations in the starting material, such as spreading in thickness and composition. As a result thereof, the used downholder force is eventually higher than is absolutely necessary, with all the above-mentioned attendant drawbacks. Moreover, the experiments cost time, material, and money, and the outcome is dependent on the expertise of those who carry out the experiments.

[0004] DE 4 038 864 discloses a method in which at the beginning of deep drawing the downholder force (F_N) is preventively chosen so high that this force is greater than a counterforce (F_s) to be expected in the blank. During deep drawing, the downholder force is gradually reduced until a beginning of wrinkle formation is observed. Then the downholder force is increased to above the counterforce expected in the blank at that moment. This is repeated until, at the end of the deep drawing process, the downholder force is equal to zero. The wrinkle formation is detected by means of measuring means which measure the distance between the downholder and the die. The reproducibility of this publication lacks because it is not explained in a manner clear to those skilled in the art how to determine the counterforce to be expected. Moreover, it is remarkable that in the known proposal the exerted downholder force decreases while, as will turn out below, in the proposal according to the invention the downholder force exactly increases in the course of the process.

[0005] In this known method, too, the downholder force is therefore higher than is necessary because, at the beginning of the method and each time when wrinkle formation occurs, this force is increased to above the counterforce to be expected in the blank. Moreover, the height of the downholder force and the good action thereof is strongly dependent on the accuracy with which the counterforce can be predicted.

[0006] The invention contemplates providing a method in which at least a number of the drawbacks inherent to the known methods are removed. To this end, a method according to the invention is defined by the features of claim 1. An apparatus according to the invention is defined by the features of claim 8.

[0007] In a method according to the invention, the downholder force is initially kept relatively low and increased only when this is necessary, that is to say at a beginning wrinkle formation. It is important here that this wrinkle formation can be recognized at an early stage. In a method according to the invention, this is achieved by taking into account the thickness trend of the edge of the blank during deep drawing or a magnitude derived from this thickness trend, such as, for instance, the speed of the thickness trend. The thickness of the blank edge gradually increases during deep drawing, because the diameter of the blank gradually decreases and, therefore, material in the blank edge must be accommodated on an increasingly smaller surface. If this thickness increase were not taken into account, then every thickness increase would be considered a beginning wrinkle formation, and the downholder would wrongly be controlled, during which not only wrinkles, but also the mentioned thickness increase would be suppressed, which leads to an unnecessarily high downholder force.

[0008] In a method according to the invention, during deep drawing the downholder force is gradually increased from a relatively low value, instead of decreased from a preventively high value. As a result thereof, the downholder force will always have a lowest possible value, resulting in low frictional forces between the apparatus and the blank. Consequently, the apparatus can be operated at relatively low forces and relatively little energy and thus be of relatively light design. Moreover, at such low forces the risk of cracks of the blank will be minimal. As a result thereof, less stringent requirements can be imposed on the starting material with respect to, for instance, the homogeneity of the material, the number of imperfections in the material grid per volume unit and thickness variations in the blank. In this manner, with qualitatively inferior starting material and at correspondingly lower material cost a qualitatively good final product can yet be realized. Moreover, the freedom in materials to be used thus increases, so that new materials can more easily be used.

[0009] Another advantage over the known methods is that a counterforce to be expected in the blank need not be determined previous to deep drawing. Nor need time-consuming and expensive tests be carried out to determine a suitable beginning downholder force, which is of great advantage, particularly for relatively small product series.

[0010] Tests of applicant have shown that if during deep drawing wrinkle formation in the edge of the blank is prevented in the above-described manner, both wrinkles in the flange of the deep-drawn final product (so-called primary wrinkles) and wrinkles in the wall of the deep-drawn final product (so-called secondary wrinkles) can be effectively prevented. In this specification, the 'edge of the blank' is understood to mean the part of the blank located between the downholder and the die ring.

[0011] In a first preferred embodiment, a method according to the invention is characterized by the measures according to claim 2.

[0012] In this embodiment, a parameter relevant to wrinkle formation is measured and the downholder force is increased if this measured parameter exceeds a predetermined critical range or critical value, which range or which value is based on, at least takes into account, the above-discussed thickness increase of the blank or a magnitude derived from this thickness increase.

[0013] The downholder force can be increased stepwise, by a predetermined step size, but can, for instance, also be regulated to a desired value by means of known per se regulating algorithms, such as, for instance, a proportionally, integratingly and/or differentiatingly operating regulation, the measured parameter again being located below the mentioned critical magnitudes (range or value).

[0014] In a further elaboration of the first preferred embodiment, a method according to the invention is characterized by the measures according to claim 3.

[0015] The parameter relevant to wrinkle formation may, for instance, be the downholder opening, defined as the perpendicular distance between the downholder and the die ring. In that case, the thickness trend or the maximum thickness increase of the blank edge can be entered as critical range or critical value, respectively. For if during deep drawing the downholder opening becomes larger than the momentary thickness or the eventual maximum thickness of the blank edge, this indicates wrinkle formation. The thickness trend can be theoretically determined, by means of suitable simulation programs, but can also be measured once, previous to deep drawing of a new series of products. To this end, a constant downholder force is adjusted, at which neither wrinkle formation, nor crack formation occurs, and the downholder opening is measured during deep drawing. Since no wrinkle formation occurs, it may be assumed that the measured downholder opening is substantially equal to the thickness increase of the blank. It is assumed here that the measured thickness increase is independent of the adjusted downholder force, or at least that the influence of the height of the downholder force on the measured thickness increase is negligibly small, within the operative area of the downholder force important to the present use.

[0016] In a further elaboration of the first preferred embodiment, a method according to the invention is characterized by the measures according to claim 4.

[0017] Instead of or besides the downholder opening, the speed at which this opening changes may also function as critical magnitude. This speed may also be determined by simulation or a testing measurement, in the above-described manner. Then the speed trend may function as critical range or a speed value measured to be highest during this trend as critical value. The downholder opening speed trend is more sensitive than the downholder opening trend, so that wrinkle formation can be recognized at an even earlier stage.

[0018] Of course, both signals, the downholder opening trend and the downholder opening speed trend, may also be used side by side, the critical value or the critical range that is exceeded first being decisive of the control of the downholder.

[0019] In a second preferred embodiment, a method according to the invention is characterized by the measures according to claim 7.

[0020] In this method, not the downholder force, but the downholder position is regulated, based on a predetermined thickness trend of the blank. This thickness trend may, in the same manner as discussed before, be simulated or measured. On the basis of this thickness trend, the downholder may always be adjusted during deep drawing such that the downholder opening is substantially equal to the predetermined momentary thickness of the blank. Such a method according to the invention offers the advantage that during deep drawing the downholder opening and downholder speed need not be measured and compared with a predetermined critical value. Moreover, in this embodiment, too, the downholder force will be minimal, at least not greater than necessary, with all the attendant above-mentioned advantages.

[0021] Of course, a combination form of both preferred embodiments according to the invention is possible as well, with primarily the position of the downholder being regulated on the basis of a predetermined thickness trend of the blank and secondarily the downholder opening trend and/or downholder opening speed trend being measured so that when the predetermined thickness trend does not fully correspond with the real thickness trend (for instance, because of variations in the starting material or hysteresis in the downholder movement) correcting action can be taken by increasing the downholder force.

[0022] In the further subclaims, further advantageous embodiments of a method and apparatus according to the invention are described.

[0023] In explanation of the invention, an exemplary embodiment of a deep drawing apparatus and a method according to the invention will be elucidated in more detail with reference to the drawing. In this drawing:

Fig. 1 schematically shows a deep drawing apparatus according to the invention;

Fig. 2 shows a diagram in which the trends of the upper and lower limits of the admissible downholder force are plotted as a function of the deep drawing ratio;

Fig. 3 shows a testing measurement with a downholder force for determining a critical value and/or range in which wrinkle formation occurs;

Fig. 4 a measurement in which the downholder opening and the downholder force are plotted against time, with and without regulation according to the invention;

Fig. 5A shows a simulation of the speed trend of the downholder opening (v_o) during deep drawing;

Fig. 5B shows a simulation of the downholder force (F_N), regulated on the basis of the speed from Fig. 5A;

Fig. 6 shows a photograph of a deep drawn product, with and without regulation according to the invention;

Fig. 7 shows a deep drawn product with primary and secondary wrinkles.

[0024] Fig. 1 shows an apparatus 1 for deep drawing products, with which wrinkle formation in those products can be reduced and preferably be completely suppressed. In this specification, wrinkle formation is understood to mean the formation of both primary wrinkles 21 in a flange 6 of the deep drawn product 15 and secondary wrinkles 22 in wall parts 25 of the product 15, as illustrated in Fig. 7. The apparatus and method according to the invention are directed to suppressing both types of wrinkles.

[0025] The apparatus 1 comprises a die 2 provided with a die opening 3 and a punch 4 arranged above this die opening 3. This punch 4 can be moved by means of suitable positioning means 7 into the opening 3, as shown in Fig. 1 on the right side. A blank 5 of starting material placed over the opening 3 is thereby forced into the opening 3 and deformed between the walls of this opening 3 and the punch 4 to a desired final product 15. As appears from a comparison of the left and the right half of Fig. 1, the starting diameter Do of the blank 5 gradually decreases during this deep drawing, which is accompanied by an increase in the thickness d of the edge 6 and can further lead to wrinkle formation.

[0026] In order to prevent the edge 6 from wrinkling and rising during deep drawing, a ring-shaped downholder 8 is arranged around the punch 4, which downholder can be moved with suitable positioning means 9 towards a die ring 10 extending around the die opening 3 while clamping the edge 6 of the blank 5. A downholder force F_N exerted on the edge 6 by the downholder 8 will thereby increase according as the downholder opening $S_{o,}$ defined as the perpendicular distance between the downholder 8 and the die ring 10, increases.

[0027] During deep drawing, the downholder force F_N must remain between two extreme limits, a lower limit $F_{N,min}$ and an upper limit $F_{N,max}$. These limits are graphically shown in Fig. 2, as a function of the deep drawing ratio. When the downholder force F_N falls below the minimum limit $F_{N,min}$, wrinkles will be formed in the product, while at exceeding the maximum limit $F_{N,max}$ cracks will be formed in the product 15. In practice, the downholder force F_N is therefore adjusted to a 'safe' distance between both limits, so that a certain safety margin is present, in connection with possible spreading in the starting material (composition, thickness, etc.).

[0028] In a method according to the invention, the downholder force F_N is contrarily exactly kept as close to the lower limit $F_{N,min}$ as possible. The risk of crack formation will thus be reduced to a minimum. Moreover, this will also limit frictional forces F_w occurring during deep drawing between the blank 5 and the downholder 8 and the die ring 10, since these frictional forces are proportional to the downholder force F_N. Lower frictional forces ensure that less lubricant suffices, that the deep drawing process can take place under lower forces, with less work, and that the whole arrangement can be of lighter design.

[0029] In order to keep the downholder force F_N as low as possible, at the beginning of deep drawing it is adjusted according to the invention to a low value and increased only if wrinkle formation occurs. Then the downholder force is increased to a value necessary to suppress the detected wrinkles. The downholder force F_N will thus always be not greater than necessary to suppress the momentary wrinkle formation.

[0030] For this method to function well, it is important to be able to detect wrinkle formation at an early stage. It has been found that both the downholder opening trend s_o and the derivative thereof over time, the downholder opening speed trend v_o, are measuring signals usable therefor. For these signals s_o and v_o, a critical value can be determined in a manner to be described below in more detail, exceeding of which involves wrinkle formation.

[0031] The deep drawing apparatus 1 of Fig. 1 is therefore provided with measuring means 11, with which the mentioned downholder opening trend s_o and/or downholder opening speed trend v_o can be measured. These measuring means 11 may, for instance, comprise an optical, capacitive or magnetic sensor. The measuring means 11 are connected to a control 12, which is provided with means for comparing the measuring signals with a critical value or critical range adjusted for those signals, and which control 12 is further arranged to move, in case of exceeding the mentioned critical magnitudes, the downholder 8 towards the die 2 by means of the positioning means 9. These positioning means 9 may, for instance, comprise a piston-cylinder assembly, an electrically driven screw spindle, a piezo-electric element, or the like.

[0032] Previous to deep drawing a new product series, the critical values can be determined during a testing measurement, by measuring, during this test, the downholder opening trend s_o as shown in Fig. 3. It is clearly visible that the downholder opening s_o initially has a substantially constant value (range I-II) and then gradually increases at a constant inclination (range II-III) corresponding with a constant downholder opening speed v_o. From point III, the measured downholder opening trend s_o shows a bend, and this trend increases more rapidly, which indicates wrinkle formation P. On the basis of this measurement, therefore, the range I-III can be implemented in the control 12 as the sought critical downholder opening range. Instead thereof, bend point III may also be introduced as critical downholder opening value. When a downholder opening trend s_o measured during deep drawing exceeds the critical range or the critical value, the thickness increase is greater than may be expected on the basis of the testing measurement, which indicates wrinkle formation.

[0033] In a slightly modified variant of the above-described method for determining the critical values, the deep drawing testing measurement may also be carried out at such a high downholder force F_N that neither wrinkle formation, nor crack formation will occur. This allows for the assumption that a downholder opening trend s_o measured during this test fully corresponds with the thickness increase of the edge 6 of the blank 5. This measured downholder opening trend may therefore be implemented in the control 12 as critical range. Instead thereof, the maximally measured thickness increase may also be introduced as critical value.

[0034] In a comparable manner, besides or instead of the downholder opening, the speed v_o at which this downholder opening changes may also be measured during the mentioned testing measurement. This measured speed trend or a speed value measured to be highest during this measurement can be introduced into the control 12 as critical range or critical value for the downholder opening speed trend.

[0035] When a downholder opening speed v_o measured during deep drawing exceeds this critical range or this critical value, this indicates wrinkle formation, since the downholder opening increases more rapidly than may be expected on the basis of the normal thickness increase.

[0036] Besides, it is pointed out that the critical speed value can also be determined by the inclination of range II-III in Fig. 3.

[0037] Fig. 4 shows a measurement of the downholder opening s_o and the downholder force F_N over time, with the thinly drawn lines representing the trend without regulation according to the invention, while the thickly drawn lines represent the trend when the downholder force F_N is controlled on the basis of the critical downholder opening determined in Fig. 3. It is clearly visible that the downholder force F_N is stepwise increased from the critical value determined in Fig. 3 (bend point III) and thus effectively suppresses (see thickly drawn s_o line) wrinkle formation (see thinly drawn s_o line).

[0038] Fig. 4 further clearly shows that the downholder force initially begins relatively low and is increased only if this is actually necessary. The force may be increased stepwise, at a predetermined step size, or may be increased proportionally to the measured deviation. Also possible are other known per se regulation techniques, in which, for instance, use is made of integrating and/or differentiating actions. The apparatus may also be provided with a self-learning regulation, in which the step size of the force F_N is initially adjusted by an operator, and the regulation itself adapts this value in the course of the process, on the basis of fed back measuring data.

[0039] In Fig. 5A,B is shown a simulation in which the downholder force is regulated on the basis of the measured opening speed v_o and a critical speed value predetermined in the above-described manner, which, in the shown case, was approximately 1×10^{-4}. It is clearly visible how the downholder force F_N is increased stepwise, each time when the downholder opening speed exceeds the critical value. It is also visible that the increase of the downholder force F_N is greater according as the exceeding of the critical value is greater.

[0040] Fig. 6 shows, on the left side, a flange 6' of a product 15', manufactured with a conventional deep drawing method (see the thinly drawn lines in Fig. 4), while next to this, on the right side, a product 15 is shown, which has been manufactured with a method according to the invention (see the thickly drawn lines in Fig. 4). It clearly appears that the product according to the present method substantially has no wrinkles.

[0041] It will be clear that the critical values for the downholder opening and the opening speed depend on the starting material and the desired final product. These values are therefore determined again, preferably preceding each new product series. This may be done by means of a testing measurement, as described above. In case of sufficient material data and process data, these values may also be simulated by means of known per se software packages, so that no testing measurements at all need be carried out anymore.

[0042] In an alternative embodiment of a method according to the invention, not the downholder force is regulated on the basis of a measured beginning of wrinkle formation (feed-back regulation), but the position of the downholder and hence the downholder opening are regulated according to a predetermined range, such that the mentioned downholder opening corresponds with the thickness trend of the blank 5 to be expected (forward regulation). The thickness trend to be expected may be determined in the same manner as described before with reference to Fig. 3. Such a forward regulation has the advantage that during the actual deep drawing no downholder opening or speed need be measured, so that a very simple apparatus, without measuring means and without advanced control, suffices.

[0043] The invention is by no means limited to the exemplary embodiments shown in the specification and the drawing. Many variations thereof are possible within the scope of the invention defined by the claims.

[0044] Thus, depending on, inter alia, the distance over which deep drawing is effected and the thickness of the starting blank, deep drawing may take place in one or more steps. Furthermore, the forward position regulation and feed-back force regulation may be combined, the force regulation being able to correctingly act on the position regulation.

Claims

1. A method for deep drawing a product from a blank, in which, during deep drawing, the blank is held near its edge by a downholder against a die ring cooperating with the downholder, thereby preventing, at least reducing wrinkle formation in the blank, by controlling the downholder, **characterized in that** at the beginning of deep drawing the downholder (8) is adjusted such that a downholder force (F_N) exerted by the downholder (8) on the edge (6) of the blank (5) is relatively small, that is, not greater than necessary to suppress momentary wrinkle formation and the further control of the downholder (3) occurs on the basis of a predetermined thickness trend of said edge (6) during deep drawing and/or a trend or critical value derived from this thickness trend.

2. A method according to claim 1, **characterized in that** during deep drawing a parameter relevant to the wrinkle formation is measured and compared with a critical value at which wrinkle formation occurs, which critical value is predetermined, based on the thickness trend of the blank edge (6) and/or a signal derived from this thickness trend, and in which, when the measured parameter exceeds or threatens to exceed this critical value, the downholder (8) is controlled such that a downholder force (F_N) exerted on the edge (6) by the downholder (8) increases and the measured parameter falls below the critical value.

3. A method according to claim 2, **characterized in that** the parameter relevant to wrinkle formation is the downholder opening (s_o), defined as the perpendicular distance between the downholder (8) and the die ring (10), and the critical value is the predetermined thickness trend or the predetermined maximum thickness increase of the edge (6).

4. A method according to claim 2, **characterized in that** the parameter relevant to wrinkle formation is the speed (v_u) at which the downholder opening changes, and the critical value is the predetermined speed trend or the predetermined maximum speed at which the blank edge increases in thickness during deep drawing.

5. A method according to any one of claims 2-4, **characterized in that** the critical value is measured during a testing session, previous to deep drawing.

6. A method according to any one of claims 2-4, **characterized in that** the critical value is simulated by means of a dynamic model of the blank (5) and the deep drawing process.

7. A method according to claim 1, in which the position of the downholder (8) is controlled according to a predetermined range, such that during deep drawing the downholder opening (s_o), defined as the perpendicular distance between the downholder (8) and the die ring (10) substantially corresponds with a predetermined thickness trend of the edge (6) to be expected during deep drawing.

8. An apparatus for deep drawing a product from a blank (5), comprising a downholder (8), a die ring (10) cooperating therewith, for holding an edge (6) of the blank (5) during deep drawing, a control (12) and positioning means (9) for moving the downholder (8), **characterized in that** the control (12) is provided with means for storing therein a desired downholder opening trend (s_o), downholder opening speed trend (v_o) and/or a critical value derived therefrom, and is arranged to control the positioning means (9) such that the movement of the downholder (8) is in agreement with the stored downholder opening trend (s_o), downholder opening speed trend (v_o) and/or a critical value derived therefrom.

9. An apparatus according to claim 8, in which the control (12) is arranged to control the positioning means (9) such that a distance between the downholder (8) and the die ring (10) is in agreement with the stored downholder opening trend (s_o) or a critical value derived therefrom.

10. An apparatus according to claim 8 or 9, in which measuring means (11) are provided to measure the downholder opening trend (s_o), the downholder opening speed trend (v_o) and/or a critical value derived therefrom, and in which the control (12) comprises means for comparing signals measured with the measuring means (11) with a downholder opening trend (s_o), downholder opening speed trend (v_o), stored in the control (12) and/or a critical value derived therefrom, and in which the control (12) is arranged to control, on the basis thereof, the downholder (8) such that the movement, speed or critical value of the downholder (8) derived therefrom is in agreement with the stored downholder opening trend, downholder opening speed trend and/or the critical value derived therefrom.

11. A apparatus according to any one of claims 8-10, **characterized in that** the measuring means (11) comprise a contactless sensor, for instance an optical, capacitive or magnetic sensor

Patentansprüche

1. Verfahren zum Tiefziehen eines Produktes aus einer Platte, bei dem während des Tiefziehens die Platte nahe ihres Randes durch einen Niederhalter gegen einen Ziehring gehalten wird, der mit dem Niederhalter zusammenwirkt, wodurch durch Steuerung des Niederhalters die Bildung von Falten in der Platte verhindert oder wenigstens reduziert wird, **dadurch gekennzeichnet, dass** zu Beginn des Tiefziehens der Niederhalter (8) so eingestellt wird, dass eine Niederhaltekraft (F_N), die durch den Niederhalter (8) auf den Rand (6) der Platte (5) ausgeübt wird, relativ klein ist, d.h. nicht größer als notwendig, um eine momentane Faltenbildung zu unterdrücken, und dass die weitere Steuerung des Niederhalters (3) auf Grundlage eines vorgegebenen Dickentrends des Randes (6) während des Tiefziehens und/oder eines Trends oder eines aus dem Dickentrend abgeleiteten kritischen Wertes erfolgt.

2. Verfahren nach Anspruch 1, **dadurch gekennzeichnet, dass** während des Tiefziehens ein für die Faltenbildung relevanter Parameter gemessen und mit einem kritischen Wert verglichen wird, bei dem Faltenbildung auftritt, wobei der kritische Wert vorher bestimmt ist auf Grundlage des Dikkentrends des Plattenrandes (6) und/oder eines aus dem Dikkentrend abgeleiteten Signals, und wobei, wenn der gemessene Parameter den kritischen Wert überschreitet oder diesen zu überschreiten droht, der Niederhalter (8) so gesteuert wird, dass die auf den Rand (6) durch den Niederhalter (8) ausgeübte Niedehaltekraft (F_N) steigt und der gemessene Parameter unter den kritischen Wert fällt.

3. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** der für die Faltenbildung relevante Parameter die Niederhalteröffnung (s_0) ist, die als der senkrechte Abstand zwischen dem Niederhalter (8) und dem Ziehring (10) definiert ist, und dass der kritische Wert der vorgegebene Dickentrend oder der vorgegebene maximale Dickenanstieg des Randes (6) ist.

4. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** der für die Faltenbildung relevante Parameter die Geschwindigkeit (v_0) ist, mit der sich die Niederhalteröffnung ändert, und dass der kritische Wert der vorgegebene Geschwindigkeitstrend oder die vorgegebene maximale Geschwindigkeit ist, mit der der Plattenrand während des Tiefziehens in seiner Dicke anwächst.

5. Verfahren nach einem der Ansprüche 2 - 4, **dadurch gekennzeichnet, dass** der kritische Wert während eines Testlaufs vor dem Tiefziehen gemessen wird.

6. Verfahren nach einem der Ansprüche 2 - 4, **dadurch gekennzeichnet, dass** der kritische Wert mittels eines dynamischen Modells der Platte (5) und des Tiefziehvorgangs simuliert wird.

7. Verfahren nach Anspruch 1, bei dem die Position des Niederhalters (8) gemäß einem vorgegebenen Bereich gesteuert wird, so dass während des Tiefziehens die Niederhalteröffnung (s_0), definiert als der senkrechte Abstand zwischen dem Niederhalter (8) und dem Ziehring (10), im Wesentlichen einem vorgegebenen Dickentrend des Randes (6) entspricht, der während des Tiefziehens zu erwarten ist.

8. Vorrichtung zum Tiefziehen eines Produkts aus einer Platte (5), mit einem Niederhalter (8), einem Ziehring (10), der damit zusammenwirkt, um einen Rand (6) der Platte während des Tiefziehens halten, einer Steuerung (12) und einer Positioniereinrichtung (9) zum Bewegen des Niederhalters (8), **dadurch gekennzeichnet, dass** die Steuerung (12) mit Einrichtungen zum Speichern eines gewünschten Niederhalteröffnungstrends (s_0), eines Niederhalteröffnungsgeschwindigkeitstrends (v_0) und/oder eines daraus abgeleiteten kritischen Wertes versehen ist und dazu ausgestaltet ist, um die Positioniereinrichtung (9) so zu steuern, dass die Bewegung des Niederhalters (8) mit dem gespeicherten Niederhalteröffnungstrend (s_0), dem Niederhalteröffnungsgeschwindigkeitstrend (v_0) und/oder einem daraus abgeleiteten kritischen Wert übereinstimmt.

9. Vorrichtung nach Anspruch 8, bei dem die Steuerung (12) dazu ausgelegt ist, um die Positioniereinrichtung (9) so zu steuern, dass der Abstand zwischen dem Niederhalter (8) und dem Ziehring in Übereinstimmung mit dem gespeicherten Niederhalteröffnungstrend (so) oder einem daraus abgeleiteten kritischen Wert ist.

10. Vorrichtung nach Anspruch 8 oder 9, bei der eine Messeinrichtung (11) vorgesehen ist, um den Niederhalteröffnungstrend (s_0), den Niederhalteröffnungsgeschwindigkeitstrend (v_0) und/oder einen daraus abgeleiteten kritischen Wert zu messen, und bei der die Steuerung (12) eine Einrichtung zum Vergleichen der mit der Messeinrichtung (11) gemessenen Signale mit einem Niederhalteröffnungstrend (s_0), einem Niederhalteröffnungsgeschwindigkeitstrend (v_0), die in der Steuerung (12) gespeichert sind, und/oder einem kritischen, daraus abgeleiteten Wert aufweist und bei der die Steuerung (12) dazu ausgelegt ist, den Niederhalter (8) auf Grundlage dessen so zu steuern, dass die Bewegung, die Geschwindigkeit oder der daraus abgeleitete kritische Wert des Niederhalters (8) in Übereinstimmung mit dem gespeicherten Niederhalteröffnungstrend, dem

gespeicherten Niederhalteröffnungsgeschwindigkeitstrend und/oder dem gespeicherten, daraus abgeleiteten kritischen Wert ist.

11. Vorrichtung nach einem der Ansprüche 8 - 10, **dadurch gekennzeichnet, dass** die Messeinrichtung (11) einen kontaktlosen Sensor umfasst, zum Beispiel einen optischen, kapazitiven oder magnetischen Sensor.

Revendications

1. Procédé d'emboutissage profond d'un produit à partir d'une ébauche, dans lequel, pendant un emboutissage profond, l'ébauche est maintenue à proximité de son bord par un applicateur, contre un anneau de matrice coopérant avec l'applicateur, en empêchant ainsi, au moins en réduisant une formation de pli dans l'ébauche, en commandant l'applicateur, **caractérisé en ce qu'**au début de l'emboutissage profond, l'applicateur (8) est ajusté de telle sorte qu'une force d'applicateur (F_N) exercée par l'applicateur (8) sur le bord (6) de l'ébauche (5) est relativement petite, c'est-à-dire n'est pas plus grande que nécessaire pour supprimer une formation de pli momentanée et la commande ultérieure de l'applicateur (8) a lieur sur la base d'une tendance de l'épaisseur prédéterminée dudit bord (6) pendant un emboutissage profond et/ou d'une tendance ou d'une valeur critique dérivée de cette tendance de l'épaisseur.

2. Procédé selon la revendication 1, **caractérisé en ce que** pendant un emboutissage profond, un paramètre concernant la formation de pli est mesuré et comparé à une valeur critique au niveau de laquelle une formation de pli a lieu, laquelle valeur critique est prédéterminée, sur la base de la tendance de l'épaisseur du bord d'ébauche (6) et/ou d'un signal dérivé de cette tendance de l'épaisseur, et dans lequel, lorsque le paramètre mesuré dépasse ou menace de dépasser cette valeur critique, l'applicateur (8) est commandé de telle sorte qu'une force d'applicateur (F_N) exercée sur le bord (6) par l'applicateur (8) augmente et le paramètre mesuré tombe en dessous de la valeur critique.

3. Procédé selon la revendication 2, **caractérisé en ce que** le paramètre concernant la formation de pli est l'ouverture d'applicateur (S_0), définie comme la distance perpendiculaire entre l'applicateur (8) et l'anneau de matrice (10), et la valeur critique est la tendance de l'épaisseur prédéterminée ou l'augmentation d'épaisseur maximum prédéterminée du bord (6).

4. Procédé selon la revendication 2, **caractérisé en ce que** le paramètre concernant la formation de pli est la vitesse (V_0) à laquelle l'ouverture d'applicateur change, et la valeur critique est la tendance de la vitesse prédéterminée ou la vitesse maximum prédéterminée à laquelle le bord d'ébauche augmente d'épaisseur pendant un emboutissage profond.

5. Procédé selon l'une quelconque des revendications 2 à 4, **caractérisé en ce que** la valeur critique est mesurée pendant une session d'essai, avant emboutissage profond.

6. Procédé selon l'une quelconque des revendications 2 à 4, **caractérisé en ce que** la valeur critique est simulée par l'intermédiaire d'un modèle dynamique de l'ébauche (5) et du traitement d'emboutissage profond.

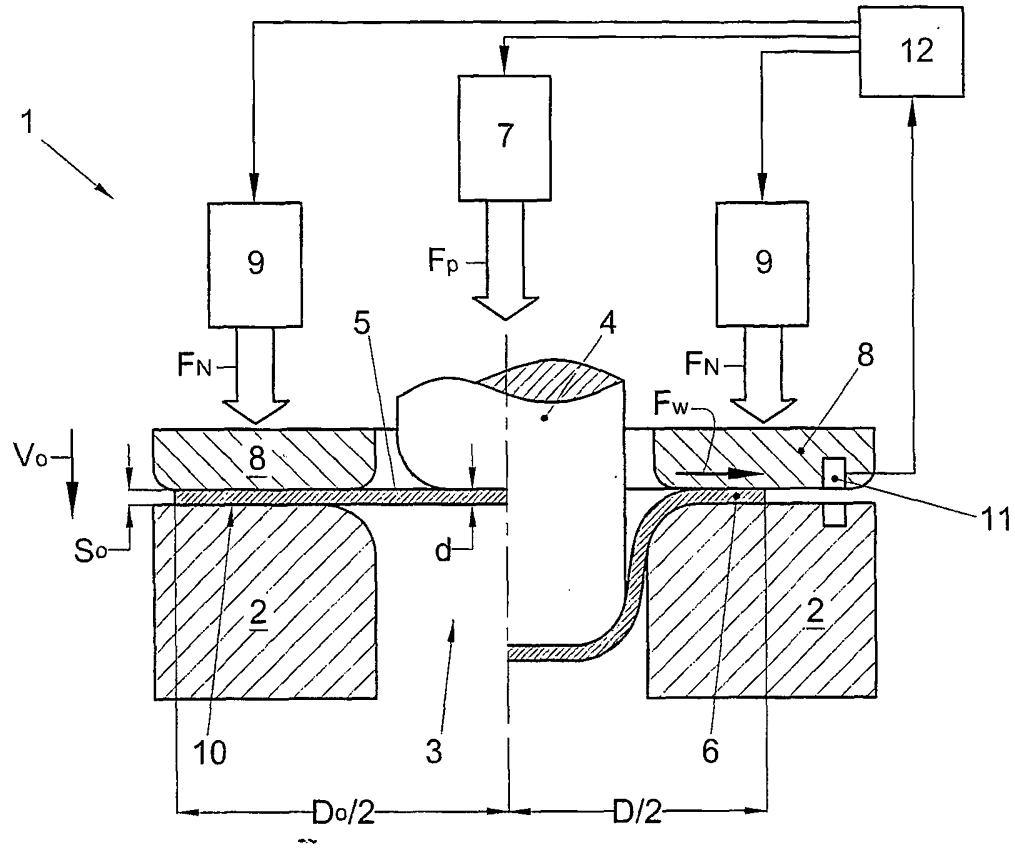
7. Procédé selon la revendication 1, dans lequel la position de l'applicateur (8) est commandée conformément à une plage prédéterminée, de sorte que pendant un emboutissage profond l'ouverture d'applicateur (S_0), définie comme la distance perpendiculaire entre l'applicateur (8) et l'anneau de matrice (10), correspond sensiblement à une tendance prédéterminée de l'épaisseur du bord (6) attendue pendant un emboutissage profond.

8. Appareil d'emboutissage profond d'un produit à partir d'une ébauche (5), comportant un applicateur (8), un anneau de matrice (10) coopérant avec celui-ci, pour maintenir un bord (6) de l'ébauche (5) pendant un emboutissage profond, une commande (12) et des moyens de positionnement (9) pour déplacer l'applicateur (8), **caractérisé en ce que** la commande (12) est munie de moyens pour mémoriser dans ceux-ci une tendance de l'ouverture d'applicateur voulue (S_0), une tendance de la vitesse d'ouverture d'applicateur (V_0) et/ou une valeur critique dérivée de celles-ci, et est agencée pour commander les moyens de positionnement (9) de sorte que le déplacement de l'applicateur (8) est conforme à la tendance d'ouverture d'applicateur (S_0), la tendance de la vitesse d'ouverture d'applicateur (V_0) et/ou une valeur critique dérivée de celles-ci mémorisées.

9. Appareil selon la revendication 8, dans lequel la commande (12) est agencée pour commander les moyens de positionnement (9) de telle sorte que la distance entre l'applicateur (8) et l'anneau de matrice (10) est conforme à la tendance de l'ouverture de l'applicateur (S_0) ou à une valeur critique dérivée de celles-ci mémorisées.

10. Appareil selon la revendication 8 ou 9, dans lequel des moyens de mesure (11) sont fournis pour mesurer la tendance de l'ouverture de l'applicateur (S_0), la tendance de la vitesse d'ouverture de l'applicateur (V_0) et/ou une valeur critique dérivée de celles-ci, et dans lequel la commande (12) comporte des moyens pour comparer des signaux mesurés à l'aide des moyens de mesure (11) avec une tendance de l'ouverture de l'applicateur (S_0), une tendance de la vitesse d'ouverture de l'applicateur (V_0), mémorisées dans la commande (12) et/ou une valeur critique dérivée de celles-ci, et dans lequel la commande (12) est agencée pour commander, sur la base de celles-ci, l'applicateur (8) de telle sorte que le déplacement, la vitesse ou la valeur critique de l'applicateur (8) dérivés de celles-ci, sont conformes à la tendance de l'ouverture d'applicateur, la tendance de la vitesse d'ouverture d'applicateur et/ou la valeur critique dérivées de celles-ci mémorisées.

11. Appareil selon l'une quelconque des revendications 8 à 10, **caractérisé en ce que** les moyens de mesure (11) comportent un capteur sans contact, par exemple un capteur optique, capacitif ou magnétique.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12
7
9
9
Fp
5
4
8
FN
FN
Fw
Vo
8
11
So
d
2
2
10
3
6
Do/2
D/2

Fig. 1

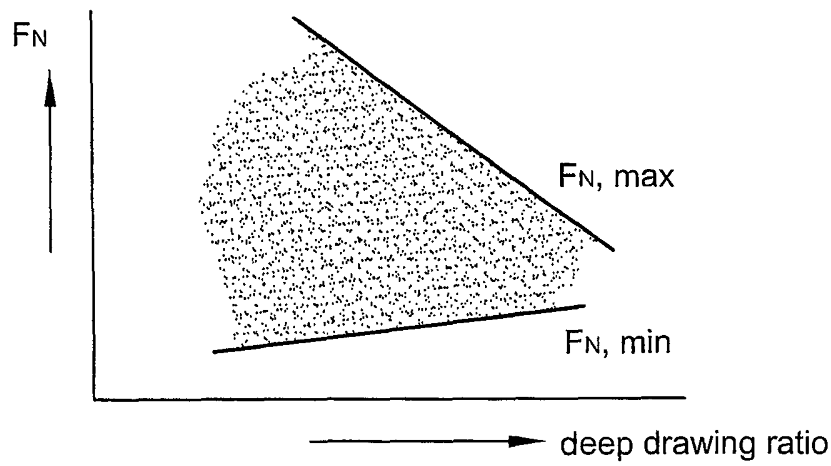
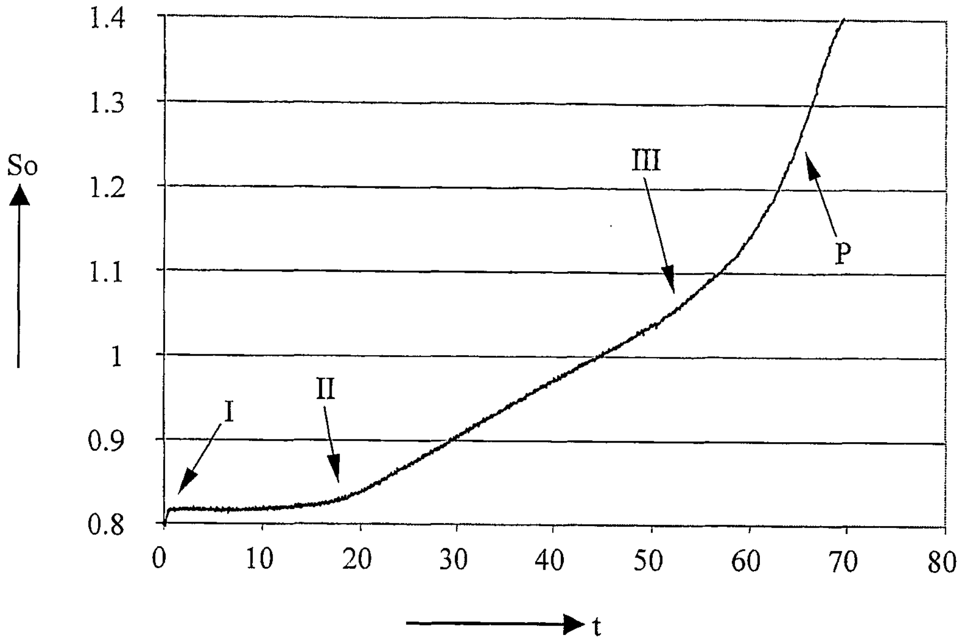

FN
FN, max
FN, min
deep drawing ratio

Fig. 2



So
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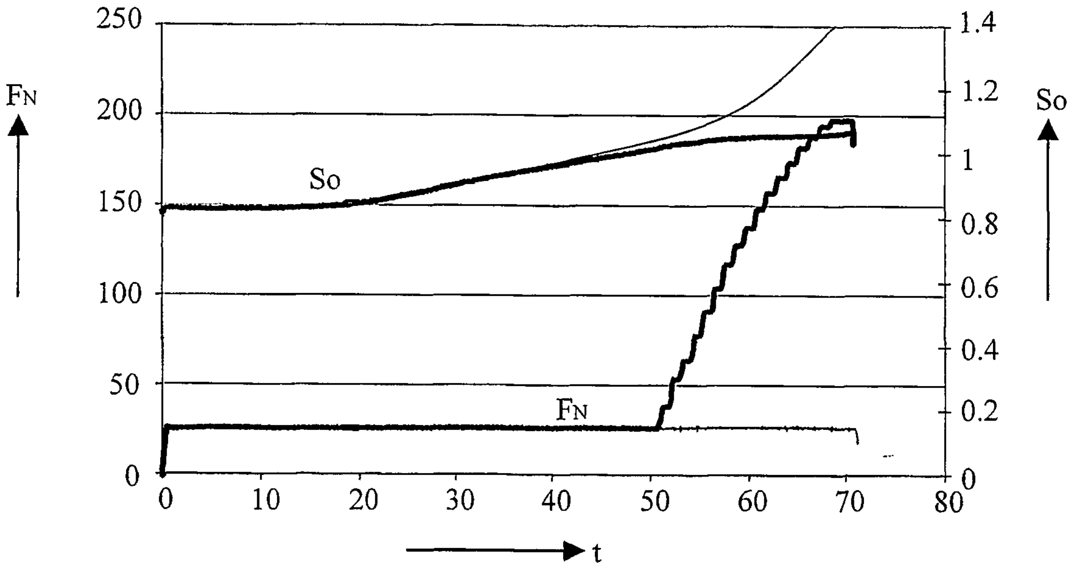
1.2
1.1
1
0.9
0.8
0
10
20
30
40
50
60
70
80
I
II
III
P
t

Fig. 3



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200
150
100
50
0
So
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1.2
1
0.8
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0
0
10
20
30
40
50
60
70
80
t

Fig. 4

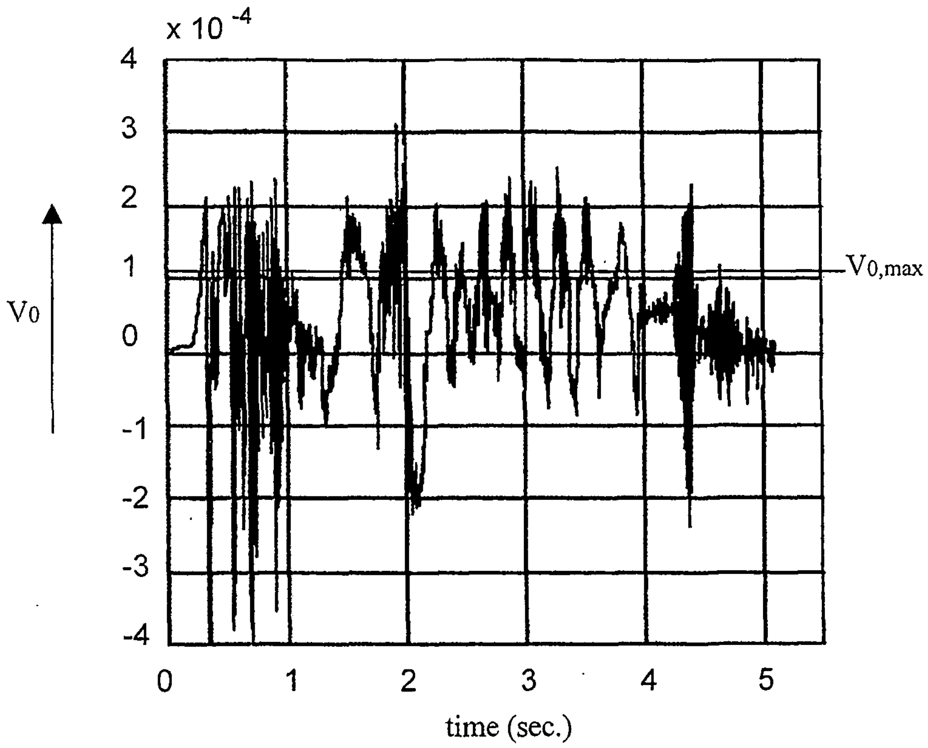
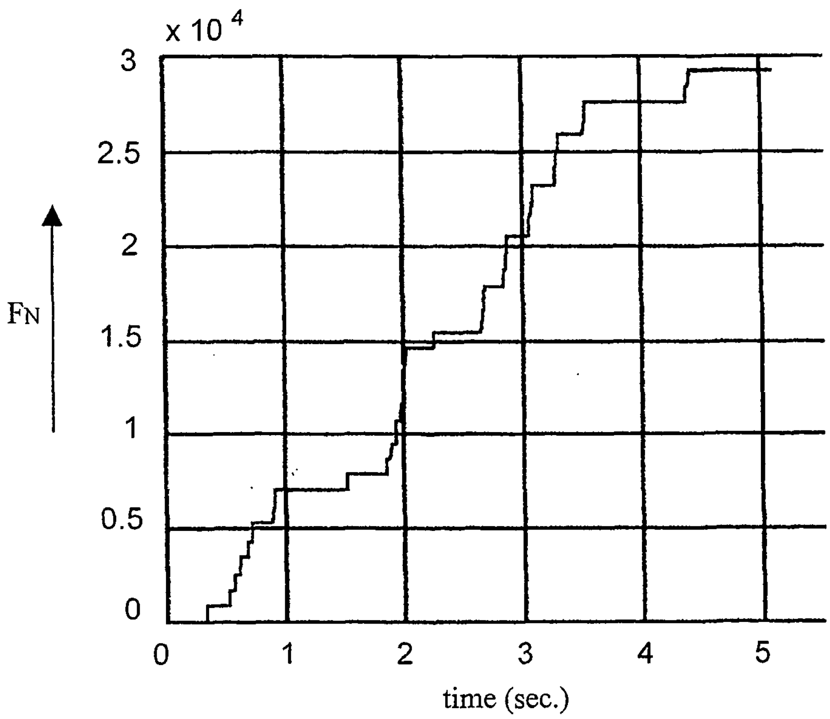

x 10 -4
4
3
2
1
0
-1
-2
-3
-4
V0
V0,max
0
1
2
3
4
5
time (sec.)

Fig. 5A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FN
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2
3
4
5
time (sec.)

Fig. 5B

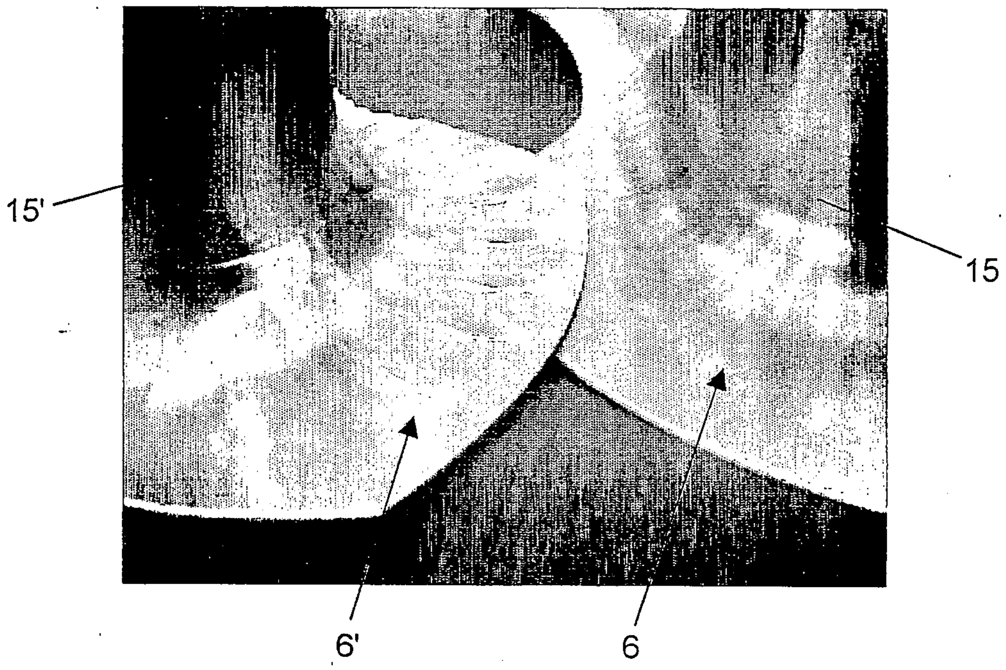

Fig. 6

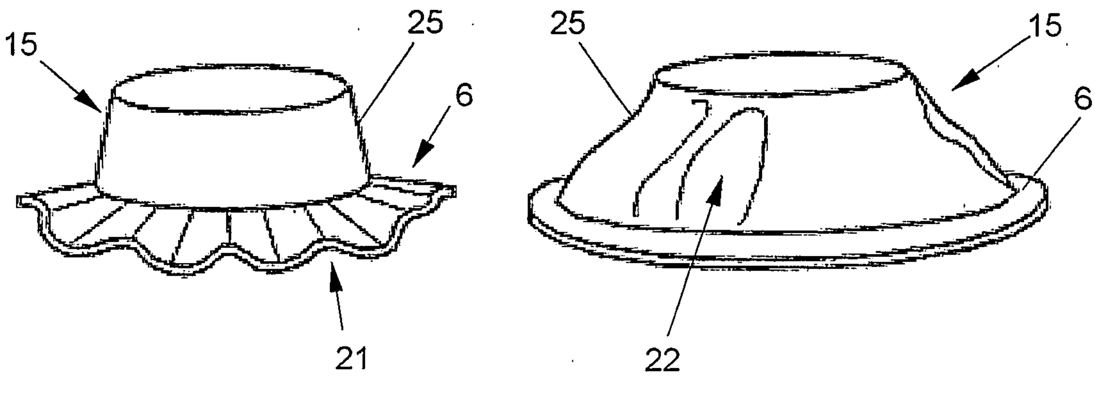

Fig. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- DE 4038864 A **[0001]**
- DE 4038864 **[0004]**