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(54) SHEET OF COLD ROLLED MATERIAL AND METHOD FOR ITS MANUFACTURE

BLECH AUS KALTGEWALZTEM MATERIAL UND VERFAHREN ZU DESSEN HERSTELLUNG

TÔLE DE MATÉRIAU LAMINÉ À FROIDET PROCÉDÉ POUR SA FABRICATION

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Description

[0001] The present invention relates generally to sheet material and more specifically to sheet material having projections on its surfaces, according to the preamble of claim 1 and to a method for forming sheet material according to the preamble of claim 9 (see for example EP-B-0891234).

[0002] As referred to herein, sheet material of the kind specified refers to sheet material having on both of its faces a plurality of rows of projections, each projection having been formed by deforming the sheet material locally to leave a corresponding depression at the opposite face of the material. This deformation is effected by a forming tool and results in both plastic strain hardening and in an increase of the effective thickness thereof. Sheet material of the kind specified is stiffer than the plain sheet material from which it is formed and the mass of material required for a particular duty can be reduced by using sheet material of the kind specified in place of plain sheet material.

[0003] The magnitude and distribution of plastic strain exerted on the sheet material depends on a number of factors including, *inter alia,* the depth of penetration of the forming portions of the tool and the geometry of the forming portions.

[0004] An further example of sheet material of the kind specified is disclosed in EP0674551, which is owned by the current applicant, wherein the sheet material is provided with the relative positions of the projections and depressions such that lines drawn on a surface of the material between adjacent rows of projections and depressions are non-linear. The projections are formed by forming tools having teeth with four flanks, wherein each flank faces a direction between the axial and circumferential directions of the rolls.

[0005] A further factor which affects the magnitude and distribution of plastic strain in such an arrangement is the layout or concentration of teeth in the forming tool.

[0006] According to a first aspect of the invention there is provided sheet of cold rolled material having on both of its surfaces rows of projections and rows of depressions, the projections on one surface corresponding with the depressions on the other surface the relative positions of the projections and depressions being such that lines drawn on a surface of the sheet between adjacent rows of projections are non-rectilinear, the sheet having a base gauge G, characterised in that each projection has a substantially continuous region of peak plastic strain at or about its apex and is thinned by no more than 25% of its base gauge G.

[0007] Preferably, the base of each depression may comprise two or more different radii of curvature.

[0008] The projections and/or depressions are preferably arranged in rectilinear and/or helical rows. The base of each depression may comprise a first radius dr_1, for example in a first direction. The depressions may comprise a second radius dr_2, for example in a second and/or longitudinal and/or rolling direction with respect to a length of the sheet material. The first direction may be different from the second direction, for example at 45 degrees therefrom. The radius of curvature along the first radius may be different from the radius of curvature along the second radius.

[0009] The depressions may further comprise a third radius dr_3, for example in a third direction orthogonal to the first direction. The depressions may further comprise a fourth radius dr_4, for example in a fourth direction orthogonal to the second direction. The first and third radii dr_1 and dr_3 may be equal, with the second radius dr_2 and/or dr_4 being different therefrom, for example less therethan, or the same thereas.

[0010] The pitch P between adjacent depressions or between adjacent projections in each row may be at least 2.5, say 3, times the radius of curvature along the first radius dr_1. Additionally or alternatively, the pitch P is preferably between 2.5 and 3.9, for example about 3.3, say 3.32, times the radius of curvature along the first radius dr_1.

[0011] The sheet material may comprise an amplitude A. The height of projections which is sufficient to ensure that lines drawn on a surface of the material between adjacent rows of projections and depressions are not rectilinear depends upon the pitch of the projections and the pitch of the depressions in the rows.

[0012] As viewed in any cross-section in a plane which is generally perpendicular to the sheet material, the amplitude A is preferably substantially greater than the base gauge G of the material. In all such cross sections, sheet material in accordance with the invention is preferably undulatory and there is more preferably no place where the material can be cut along a straight line and the resulting cross section of the material will be rectilinear.

[0013] The amplitude A is preferably between 1.5 to 4, say 2 and 3, times the base gauge G. The base gauge G may be 2mm or greater. The base gauge G is preferably between 0.2 mm and 3.0 mm, for example 0.7 mm or 1.5mm.

[0014] The plastic strain of the material is preferably 0.05 or more. The proportion of sheet material which is subjected to significant plastic strain, that is to say plastically strained to a value of 0.05 or more, is preferably at least 65% and more preferably over 80%, for example 90% to 100%.

[0015] The sheet material may comprise steel, for example, mild steel and may be galvanised. Alternatively, the sheet material may comprise any other material capable of strain hardening and/or plastic deformation.

[0016] The sheet material may comprise a profile or shaped cross-section such as a channel section or the like for use as a, or as part of a, partition or channel stud. The projections may be formed over all or part of the shaped section.

[0017] According to a further aspect of the invention, there is provided a method of forming sheet material according to claim 12.

[0018] The method may further comprise shaping the formed sheet material, for example into a channel section.

[0019] The method may comprise urging the material such that the apex or peaks of the projections are free from contact with the other tool during forming.

[0020] The method may comprise subjecting the sheet material to a plastic strain of 0.05 or more across at least 65% of the formed area thereof.

[0021] The clearance between the teeth on one tool and the teeth on the other tool during forming may be at least 1.1 times the base gauge of the plain sheet material.

[0022] A tool suitable for carrying out the method according to the invention may comprise rows of teeth on its outer surface, each tooth comprising a rounded sheet engaging surface.

[0023] The rounded sheet engaging surface of each tooth may have a radius of curvature, the pitch between adjacent teeth in a row being between 2.5 and 3.9 times the radius of curvature.

[0024] Preferably, there is also a minimum clearance, in use, between the peak of each tooth on the one tool and the root surface of the other tool, for example to ensure material to be formed is not pinched therebetween.

[0025] The pair of tools may form part of an apparatus.

[0026] The apparatus may further comprise shaping means for shaping the sheet material. The shaping means may comprise a further pair of rollers and may be arranged to shape the formed sheet material, for example into a channel section.

[0027] Preferably, the pitch P is between 3 and 3.5, for example 3.32, times the radius of curvature R.

[0028] The radius of curvature R is preferably at least equal to the base gauge G of a sheet material to be formed and more preferably at least 1.1 times the base gauge G, for example at least 2 times the base gauge G and/or less than 3.33 times the base gauge. Thus, the pitch is preferably between 2.5 and 13 times the base gauge G, for example between 2.75 and 7.8 times the base gauge and more preferably at least 3.65 times the base gauge G.

[0029] Each tooth may have a rounded sheet engaging surface with a first radius r_1 in a first direction and/or a second radius r_2 in a second direction along the rows. The first direction may be at an acute angle in relation to the second direction. The second radius r_2 may be less than or equal to the first radius r_1.

[0030] As used herein, the term "radius" refers to the distance between the centre of the tooth base plane and the tooth face as measured along an imaginary plane extending in the direction of the radius r_1, r_2, r_3, r_4 whilst the term "radius of curvature" refers to the actual surface radius at a specific point on the surface of the tooth forming portion. Thus, a "radius" r_1, r_2, r_3, r_4 may be a compound radius of curvature having two or more radii of curvature blended together.

[0031] For the avoidance of doubt, the "direction" of a radius r_1, r_2, r_3, r_4 refers to the direction in which the plane of that radius r_1, r_2, r_3, r_4 extends.

[0032] The pitch P between adjacent teeth in a row may be at least 3.3, for example at least 3.32, times the first and/or second radii r_1, r_2. Preferably, the pitch P between adjacent teeth in a row is at least 3.3, for example at least 3.32, times the second radius r_2 measured at the point of the tooth nearest the adjacent tooth from the other tool. It is postulated that this arrangement provides sufficient clearance to avoid material pinching in use.

[0033] Preferably, the radius of curvature R is less than or equal to 6.7mm and/or the pitch is less than 15.6mm such as between 5mm and 15.6mm, for example between 5mm and 7.8mm.

[0034] The tool or tools may comprise a first dimension and a second dimension, for example where the second dimension is orthogonal to the first dimension. The rows may extend in the direction of the first and/or the second dimensions. Alternatively, the rows may extend in a direction between the first and second dimensions.

[0035] The tool or tools may comprise cylindrical rolls, for example which are rotatable about respective axes, which axes may be parallel to one another. The teeth may be arranged in helical rows. Each tooth may have a sheet engaging forming portion which is substantially free of sharp corners and/or comprises the sheet engaging surface. The first dimension may comprise a circumferential dimension and/or the second dimension may comprise an axial dimension. In this embodiment there is preferably a minimum clearance, in use, between the peak of each tooth on the one tool and the root diameter of the other tool, for example to ensure material to be formed is not pinched therebetween.

[0036] The sheet engaging surface is preferably free of sharp corners. The teeth may comprise forming portions free of sharp corners.

[0037] Each tooth may further comprise a third radius r_3, for example in the third direction orthogonal to the first direction, and/or a fourth radius r_4, for example in a fourth direction orthogonal to the second direction. The third radius r_3 may be equal to the first radius r_1 and/or the fourth radius r_4 may be equal to the second radius r_2.

[0038] The tooth may have compound or blended radii of curvatures, such that the radius of curvature on one part of the tooth's periphery blends smoothly and continuously into a second radius of curvature on another part of the tooth's periphery.

[0039] The pitch P and/or the radii r_1, r_2, r_3, r_4 and/or the spacing of the rolls are preferably selected such that the tooth forming portions cause the aforementioned plastic strain and/or material thinning to the sheet material, in use.

[0040] One embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a tooth used in the method according to the prior art;

Figure 2 is a representation of the strain distribution across a projection formed in sheet material using the tooth of Figure 1;

Figure 3 is a plan view of a fragment of one embodiment of sheet material according to the invention;

Figure 4 is a diagrammatical illustration of the forming of sheet material according to an embodiment of the method of the invention;

Figure 5 is a perspective view of the cooperation of a group of teeth having a first embodiment of tooth forming portions;

Figure 6 is a side view of the tooth forming portions of Figure 5 from direction X;

Figure 7 is a plan view of the tooth forming portions of Figure 5;

Figure 8 is a cross-section view along line B-B of Figure 7 showing sheet material being formed between the tooth forming portions;

Figure 8A is a representation of the strain distribution across a projection formed in sheet material using the tooth of Figure 8;

Figure 9 shows a second embodiment of tooth forming portions;

Figure 10 shows a third embodiment of tooth forming portions;

Figure 11 shows a fourth embodiment of tooth forming portions;

Figure 12 shows a fifth embodiment of tooth forming portions;

Figure 13 shows a sixth embodiment of tooth forming portions;

Figure 14A is a cross-sectional view of one of the tooth forming portions of Figure 13;

Figure 14B is a top view of one of the tooth forming portions of Figure 13;

Figure 15 is a perspective view of sheet material shaped into a first embodiment of channel section; and

Figure 18 is a perspective view of sheet material shaped into a second embodiment of channel section.

[0041] Figures 1 illustrates a prior art roll tooth 1 of the kind used in the prior art method disclosed in EP0891234 (which is owned by the current applicant) for forming a projection 2 in sheet material 3 as shown in Figure 2. The roll tooth 1 is a cross cut involute gear form having four flanks 4 merging to a substantially flat peak 5. The forming rolls (not shown) will include a plurality of such teeth 1, wherein the teeth 1 on adjacent rolls (not shown) intermesh to deform the sheet material 3.

[0042] The geometry and density of the teeth 1 across the surface of the rolls (not shown) is dependent upon specific requirements of the application. For example, an increase in the depth of intermeshing and/or an increase in the density of teeth 1 will result in a greater degree of work hardening as well as a greater reduction in overall length of the material.

[0043] We have observed through extensive experimentation that the practical range of depth and/or density of teeth 1 on the roll (not shown) for producing useful sheet material of the kind specified is also limited by the resulting degree of material thinning, which worsen the mechanical properties of the material. The equipment and methods of producing sheet material of the kind specified therefore requires a balance between the density and intermeshing of the teeth versus the degree of material thinning in order to optimise the forming process.

[0044] On further Investigation, we have surprisingly determined that the sharp corners 6 between the flanks 4, which are formed as a result of the manufacturing process, cause areas 7 of peak plastic strain.

[0045] As a result, a higher degree of work hardening and thinning of the material is experienced in these areas 7. The resulting strain distribution is illustrated in Figure 2. Without wishing to be limited by any particular theory we now postulate that difficulties in forming sheet material of the kind specified using a relatively thick sheet material, for example having a thickness above 1.5mm, may be attributed to this phenomenon.

[0046] It is from these surprising realisations that we have conceived and developed the present invention.

[0047] Referring now to Figure 3, there is shown a fragment of formed sheet material 10 comprising mild steel having on both of its faces a large number of projections 11 and depressions 12, each projection 11 at one face corresponding to a depression 12 at the other face. The projections 11 and depressions 12 are substantially square in shape with rounded corners.

[0048] The projections 11 and depressions 12 at one face are arranged in rectilinear rows R11 and columns C11, wherein each row R11 and each column C11 comprises alternating projections 11 and depressions 12. There are also alternating respective rows R12, R13 of projections 11 and depressions 12 which extend along a line between the directions of the rows R11 and columns C11. The rows R12, R13 extend at 45° to the rows R11 and the columns C11 in this embodiment. These rows are referred to hereinafter as helical rows R12, R13. The angle can range from 0° to 180°.

[0049] Adjacent projections 11 and depressions 12 are sufficiently close to one another for there to be no substantially flat areas of sheet material between them. Thus, the sheet material 10 as viewed in any cross-section which is generally perpendicular to the nominal or actual plane of the sheet material 10 is undulatory, thereby resulting in an effective thickness, or amplitude A, which is greater than the base gauge G of the material.

[0050] The formed sheet material 10 illustrated in Figure 3 is formed by the process illustrated in Figure 4. In this process, plain or base sheet material 17 having a base gauge G is drawn from a coil (not shown) and passes between a pair of rolls 18 and 19, each of which has at its periphery a number of teeth 30. The rolls 18, 19 are rotated about respective parallel axes 20 and 21 and the base sheet material 17 is engaged and deformed by the teeth 30 of the rolls 18, 19. Each tooth 30 pushes a part of the base sheet material 17 into a gap between teeth 30 on the other roll 18, 19 to form a projection 11 facing that other roll 18, 19 and a corresponding depression 12 facing the one roll 18, 19, thereby providing the formed sheet material 10. Thus, the overall thickness of the base sheet material 17 is increased by the presence of projections 11 on both of its faces and providing an effective thickness, or amplitude A, in the formed sheet material 10.

[0051] From the roll pair 18 and 19, the sheet material 10 may then pass between further roll pairs 22, 23 and 24 to shape the formed sheet material 10 into a channel section 27 in this embodiment. Other elongate shaped members (not shown) may also be formed.

[0052] The roll pair 18 and 19 and the further roll pairs 22, 23 and 24 are all driven by common drive means 25 of known form and preferably including an electric motor 26. The roll pairs 18 and 19, 22, 23, 24 are driven at substantially the same peripheral speed so that the base sheet material 17 passes continuously and at the same speed between the rolls 18 and 19 as the formed sheet material 10 passes between the subsequent further roll pairs 22, 23, 24.

[0053] After the formed sheet material 10 has been shaped into a channel or other section 27, it may be cut into lengths (not shown) for transportation and use.

[0054] Both of the rolls 18, 19 have substantially the same form with a first dimension, or axial length in this embodiment, and a second dimension orthogonal to the first, or circumferential dimension in this embodiment. Each roll 18, 19 includes a plurality of identical teeth 30 on its periphery, each of which teeth 30 includes a tooth forming portion 30a as shown in Figure 5. The teeth 30 are arranged in a plurality of rows which correspond to the rows R11, R12, R13 and columns C11 of the formed sheet material. It will be appreciated that the helical rows R12, R13 of teeth 30 extend along lines which extend between lines lying along the first and second dimensions. In this embodiment, the helical rows (not shown) are inclined to the axis 20, 21 of the roll 18, 19 at an angle of 45°.

[0055] Each tooth forming portion 30 is formed integrally with a tooth base portion (not shown) which in turn is formed integrally or otherwise secured to the periphery of one of the rolls 18, 19. It will be appreciated that the tooth base portions (not shown) are sized and dimensioned such that they do not impede deformation of the material in use.

[0056] The first embodiment of tooth forming portions 30a have a geometry and cooperating layout as illustrated in part in Figures 5 to 8. Each tooth forming portion 30a includes a base plane 31 which is substantially square in shape having rounded corners 32 and a smoothed depression 33 at the mid point of each side edge 34, thereby forming a four lobed shape. The side surfaces 35 of the tooth forming portion 30 project upward from the side edges 34 of the base 31 and curve toward a common smoothed apex 36, thus forming a rounded sheet engaging surface. It will be appreciated that there are no sharp corners present on the tooth forming portions 30a.

[0057] The features of the shape of the tooth forming portion 30a are defined by a series of radii r_1, r_2, r_3, r_4, each of which has a constant radius of curvature in this embodiment. However, the first and third radii r_1, r_3 are different from the second and fourth radii r_2, r_4 in this embodiment.

[0058] As used herein, the term "radius" refers to the distance between the centre of the tooth base plane 31 and the tooth face 35 as measured along an imaginary plane extending in the direction of the radius r_1, r_2, r_3, r_4 (as shown more clearly in Figure 6) whilst the term "radius of curvature" refers to the actual surface radius at a specific point on the surface of the tooth forming portion 30a. Thus, a "radius" r_1, r_2, r_3, r_4 may be a compound radius of curvature having two or more radii of curvature blended together.

[0059] For the avoidance of doubt, the "direction" of a radius r_1, r_2, r_3, r_4 refers to the direction in which the plane of that radius r_1, r_2, r_3, r_4 extends.

[0060] The first and third radii r_1, r_3 are orthogonal to one another and each extends in a direction between the first and second directions (i.e. between the axial and circumferential directions of the rolls 18, 19). As is shown, r_1, r_3 both extend at 45° to the first direction in this embodiment. The second and fourth radii r_2, r_4 extend respectively along the axial direction and circumferential (i e. rolling) direction. The pitch P between adjacent teeth 30 is equal in this embodiment along both the rectilinear rows R11 and columns C11.

[0061] In use, the sheet material 10 is passed through the rolls 18, 19 in the rolling direction RD (shown in Figure 7). Each tooth forming portion 30 from one of the rolls 18, 19 moves into and out of alignment with the space between adjacent tooth forming portions 30 in the other of the rolls 18, 19 as shown more clearly in Figures 5 to 8. As can be seen from Figure 8, the amplitude A of the formed sheet material 10 is a function of the depth D of penetration, or overlap, between the forming portions 30a, which in turn is a function of the separation of the rolls 18, 19.

[0062] The spacing and geometry of the teeth 30 in this embodiment are such that the apex or peak of a projection 11 being formed by one of the teeth 30 on one of the rolls 18, 19 is free from contact with other the roll 18, 19. This can be seen, for example, in Figure 8.

[0063] The amplitude A of the sheet material leaving the rolls 18 and 19 is preferably between 1.5 to 4, say 2 and 3, times the base gauge G of the sheet material. However, it will be appreciated that subsequent shaping of the sheet material by the roll pairs 22, 23 and 24 can reduce the amplitude A of the formed sheet material 10.

[0064] As mentioned above, the improvements in physical properties of sheet material of the kind specified are mainly attributed to the increase in effective thickness of the sheet material and the strain hardening effect which is a consequence of the plastic deformation of the material. It is therefore desirable to maximise the effective thickness or amplitude A of the formed material 10 and to maximise both the magnitude and area of plastic strain. Increasing the amplitude A will increase the magnitude of plastic strain and decreasing the pitch P will increase the area of plastic strain because of an increase in projection density.

[0065] However, the greater the magnitude of plastic strain, the greater the extent of material thinning, which adversely affects the physical properties of the sheet material.

[0066] We have determined that there is a preferable or optimum sheet engaging surface radius R which provides a balance between maximising work hardening and minimising the material thinning.

[0067] However, as mentioned above, it is desirable to minimise the pitch P in order to maximise the area of plastic strain. It has been observed that the sheet material is 'pinched' when the clearance between adjacent forming portions 30a approaches and is less than the base gauge G in use. Whilst material pinch is beneficial in terms of plastic strain and therefore strain hardening of the formed material, it can result in local thinning of the sheet material and it causes issues in manufacture due to excessive loads and roll wear issues. It is therefore preferable to avoid material pinch.

[0068] A tooth form which enables a balance to be struck between these competing factors, is achieved by providing a rounded sheet engaging surface having a radius of curvature equal to the preferable surface radius R in some areas while the radius of curvature in other areas is adjusted to prevent pinching.

Material pinching occurs in the regions where there is the least distance between intermeshing teeth. In the case of the first embodiment of tooth forming portion 30a, this is in the direction of the rectilinear rows R11 and columns C11 (i.e. direction of r_2 and r_4).

[0069] Accordingly, in this embodiment the radii r_1, r_3 of the sheet engaging surface have a radius of curvature equal to the preferable surface radius R, while the radii r_2, r_4 gradually decrease from the peak to the base portion (not shown). This provides a profile which allows for a reduced pitch P to maximise the strained area, while providing a degree of extra clearance to avoid pinching the material.

[0070] We have determined that by ensuring that the pitch P is at least 2.5 times, preferably at least 3 times, for example 3.32 times, the preferable surface radius R (i.e. the first and third radii r_1, r_3 in this embodiment) the level of strain can be maximised.

[0071] The surface radius along the radii r_1, r_2, r_3 and r_4 should be at least equal to the base gauge G, preferably 1.1 or more times the base gauge G, of the sheet material in order to ensure a relatively even strain distribution throughout the projection 11 and to minimise thinning. Figure 8a shows a representation of the plastic strain of a part of the sheet material 10 formed using the tooth geometry shown in Figures 5 to 8. As shown in Figure 8a, there is a continuous area of peak plastic strain PP around the apex of the projection 11, while the plastic strain in the quaquaversal region QQ surrounding the area PP decreases moving away from that region. The sheet material is thinned by less that 25%.

[0072] The base of the depression 12 includes four radii dr_1, dr_2, dr_3 and dr_4, which correspond generally to the four radii r_1, r_2, r_3 and r_4 of the sheet engaging surface of the tooth.

[0073] In order to further demonstrate the flexibility of the invention, reference is made to the further tooth forms shown in Figures 9 to 13.

[0074] Figure 9 shows a second embodiment of tooth 130 which includes a forming portion 130a of hemispherical form and a cylindrical base portion 130b formed integrally with the forming portion 130a. In this case, all radii r_1, r_2, r_3 and r_4 are equal to the preferable surface radius R and the pitch P_2 is such that no material pinching occurs. It will be appreciated that the pitch P_2 required to prevent material pinching will be greater for this embodiment since the second and fourth radii r_2, r_4 are equal to the first and third radii r_1, r_3.

[0075] Figure 10 shows a third embodiment of tooth 230 which includes a forming portion 230a formed integrally with a base portion 230b that is generally square in plan with rounded corners. The first and third radii r_1, r_3 in this embodiment are both equal to the preferable surface radius R, whereas the second and fourth radii r_2, r_4 each comprise a compound radius gradually decreasing toward the base portion 230b to provide suitable clearance and thereby reduce the potential for material pinch. This tooth form 230 allows for a reduced pitch P_3 with respect to the pitch P_2 of the second embodiment, thereby increasing the density of projections 11 and improving the proportion of the formed sheet material 10 which is strain hardened.

[0076] Figure 11 shows a fourth embodiment of tooth 330 which includes a forming portion 330a formed integrally with a base portion 330b that is also generally square in plan with rounded corners. The first and third radii r_1, r_3 in this embodiment are both equal to the preferable surface radius R at or adjacent to the peak 311a of the tooth 330 and comprise a compound radius gradually decreasing toward the base portion 330b. The second and fourth radii r_2, r_4 have a single radius of curvature and are smaller than the first and third radii r_1, r_3 to provide suitable clearance and thereby reduce the potential for material pinch. This tooth form 330 allows for a reduced pitch P_4 with respect to the pitch P_2 of the second embodiment since the size of the base portion 330b can be reduced for a given preferable surface radius R, thus increasing the worked area of the sheet material 10.

[0077] Figure 12 shows a fifth embodiment of tooth 430 which includes a forming portion 430a formed integrally with a base portion 430b that is also generally square in plan with rounded corners. The first and third radii r_1, r_3 in this embodiment are both equal to the preferable surface radius R at or adjacent to the peak 411a of the tooth 430 and comprise a compound radius gradually decreasing toward the base portion 430b. The second and fourth radii r_2, r_4 each comprise a compound radius gradually decreasing toward the base portion 430b to provide a region having a suitable clearance and thereby reduce the potential for material pinch. The four compound radii r_1, r_2, r_3, r_4 of the tooth form 430 provide maximum flexibility for optimising the balance between the degree of work hardening and avoiding material pinch.

[0078] Figures 13, 14A and 14B show a sixth embodiment of tooth 630 which includes a forming portion 630a formed integrally with a base portion 630b that is generally square in plan with rounded corners. All of the radii r_1, r_2, r_3, r_4 in this embodiment are equal to the preferable surface radius R at and adjacent to the peak 611 a of the tooth 430 to provide a part spheroidal surface 631 and comprise a compound radius gradually decreasing toward the base portion 430b extending from and blended with the part spheroidal surface 631. The second and fourth radii r_2, r_4 each comprise a compound radius which gradually decreases toward the base portion 430b by a steeper gradient than the first and third radii r_1, r_3, thereby providing a region having a suitable clearance to reduce the potential for material pinch.

[0079] As shown more clearly in Figures 14A and 14B, the part spheroidal surface 631 or tip area 631 is defined by a conical segment with an angle A between 0 and 180°. Clearly, if the angle A approaches 180° then the tooth form 160 will approach that of Figure 9.

[0080] The shaped sheet material 27 which results from the process illustrated in Figure 4 is suitable for use on its own or in the form of a structural member 27a, 27b as shown in Figures 15 and 16, for example a post or a beam. For these purposes, sheet material 10 of channel form 27a, 27b is particularly suitable, the channel 27a, 27b having flanges 270a, 271a, 270b and a web 272a, 272b which maintains the flanges 270a, 271a, 270b a predetermined distance apart.

[0081] The surfaces of the flanges 270a, 271 a, 270b and the web 272a, 272b include rows (R11, R12, R13) of projections 11 and depressions 12. In certain cases, projections 11 and depressions 12 may be required on only a part of the surface of the sheet material 10. The invention is applicable with especial advantage to studs 27a, 27b used in stud and panel partitions and to the channel lengths 27b in which end portions of the studs 27a, 27b are received.

[0082] For other purposes, generally flat material or section other than a channel 27 are useful, for example C-sections, U-sections, Z-sections, I sections and so on.

[0083] Sheet material of the kind specified formed in accordance with the present invention is much stiffer than the plain sheet material from which it is formed. In particular, the bending strength of such material increases dramatically.

<u>Example 1</u>

[0084] A specimen of sheet material having a base gauge G of 0.45mm was formed using a tool comprising the tooth form shown in Figure 10. The pitch of the teeth on the tool was 5.1mm, the first and third radii r_1, r_3 had a constant radius of curvature of 1.5mm, while the second and fourth radii r_2, r_4 had a composite radius of curvature.

[0085] The sheet material was formed with an amplitude A of 2.5 times the base gauge G of the material 17 with a proportion of significant plastic strain of 70% and material thinning of 15%. The formed sheet material 10 resulted in a 33% increase in bending strength over the plain sheet material from which it was formed, as measured by a 5mm displacement three point bending test.

<u>Example 2</u>

[0086] A further specimen of sheet material having a base gauge G of 0.45mm was formed using a tool comprising the same tooth form and having the same pitch as in Example 1.

[0087] The sheet material was formed with an amplitude A of 3 times the base gauge G of the material 17 with a proportion of significant plastic strain of 88% and material thinning of 23%. The formed sheet material 10 resulted in a 36% increase in bending strength over the plain sheet material from which it was formed, as measured by a 5mm displacement three point bending test.

<u>Example 3</u>

[0088] A specimen of sheet material having a base gauge G of 0.7mm was formed using a tool comprising the same tooth form and having the same pitch as in Example 1.

[0089] The sheet material was formed with an amplitude A of 2 times the base gauge G of the material 17 with a proportion of significant plastic strain of 88% and material thinning of 11%. The formed sheet material 10 resulted in a 48% increase in bending strength over the plain sheet material from which it was formed, as measured by a 5mm displacement three point bending test.

<u>Example 4</u>

[0090] A further specimen of sheet material having a base gauge G of 0.7mm was formed using a tool comprising the same tooth form and having the same pitch as in Example 1.

[0091] The sheet material was formed with an amplitude A of 2.5 times the base gauge G of the material 17 with a proportion of significant plastic strain of 96% and material thinning of 22%. The formed sheet material 10 resulted in a 62% increase in bending strength over the plain sheet material from which it was formed, as measured by a 5mm displacement three point bending test.

Example 5

[0092] A specimen of sheet material having a base gauge G of 2mm was formed using a tool comprising the tooth form shown in Figure 9. The pitch of the teeth on the tool was 9.5mm and the first, second, third and fourth radii r_1, r_2, r_3, r_4 all had a constant radius of curvature of 2.5mm.

[0093] The sheet material was formed with an amplitude A of 1.8 times the base gauge G of the material 17 with a proportion of significant plastic strain of 76% and material thinning of 24%. The formed sheet material 10 resulted in a 35% Increase in bending strength over the plain sheet material from which it was formed, as measured by a 5mm displacement three point bending test.

[0094] It will be appreciated that several variations to the embodiment disclosed are envisaged without departing from the scope of the invention as defined by the appended claims. For Instance, the forming tool or tools need not comprise inter-engaging rolls. Any suitable tool may be used such as a press or other stamping means for example.

[0095] There may be a substituted for the roll pair 18, 19 a pair of rolls which are not identical, for example, one having square teeth (not shown) and the other having elongated teeth (not shown).

[0096] In place of the roll pairs 22, 23 and 24, there may be provided an alternative device or devices for modifying the sheet material in some other way or alternatively, the sheet may be provided without modification.

[0097] Whilst helical rows are inclined at 45 degrees relative to the axis of the rolls, they may be inclined at any angle and/or they need not be arranged in helical rows. The tool need not be rolls, could be, for example, a block with a flat face and/or substantially planar

[0098] The sheet material is preferably mild steel, which may be galvanised or otherwise coated for protection against corrosion. Modification of initially plain, galvanised mild steel sheet in the manner hereinbefore described leaves the protective coating intact. The base gauge G of the plain sheet material is typically within the range 0.3 to 3mm.

[0099] It has been surprisingly found that the present invention can be used to form material with a base gauge G of 3mm whilst still showing improved strength and no noticeable material pinching.

[0100] As will be appreciated, many alternative radii r_1, r_2, r_3, r_4 are envisaged which will result in a number of different forms of rounded sheet engaging surfaces which are insistent with the invention.

[0101] The pitch P between adjacent teeth 30 in rows R11 may be different from the pitch P in the columns C11.

[0102] As used herein, the term "sheet material" embraces generally flat material, for example such as that which is described in the aforesaid European patent applications and products made by bending or shaping generally flat sheet material, examples of which products are shown in Figures 9 and 10 and mentioned in our published international patent application published as WO82/03347.

Claims

1. A sheet (10) of cold rolled material having on both of its surfaces rows (R12) of projections (11) and rows (R13) of depressions (12), the projections (11) on one surface corresponding with the depressions (12) on the other surface, the relative positions of the projections (11) and depressions (12) being such that lines drawn on a surface of the sheet (10) between adjacent rows (R12) of projections (12) are non-rectilinear, the sheet (10) having a base gauge (G), **characterised in that** each projection (11) has a substantially continuous region of peak plastic strain (PP) at or about its apex and is thinned by no more than 25% of its base gauge (G).

2. A sheet (10) as claimed in Claim 1 wherein the base of each depression (12) comprises two or more different radii of curvature.

3. A sheet (10) as claimed in Claim 1 or 2, wherein the base of each depression (12) comprises a first radius in a first direction, a second radius in a second direction along the length of the sheet material (10), the first direction being different from the second direction, wherein the radius of curvature along the first radius is different from the radius of curvature along the second radius.

4. A sheet (10) as claimed in any preceding Claim, wherein the pitch (P) between adjacent depressions (12) or between adjacent projections (11) in each row (R12, R13) is at least 2.5 times the or a radius of curvature along the or a first radius.

5. A sheet (10) as claimed in Claim 4, wherein the pitch (P) is between 2.5 and 3.9 times the radius of curvature along the first radius.

6. A sheet (10) as claimed in any preceding Claim wherein the or a radius of curvature is at least equal to the base gauge (G).

7. A sheet (10) as claimed in any preceding Claim, wherein the amplitude (A) of the sheet (10) is between 1.5 and 4 times the base gauge (G) of the material (17) from which the sheet (10) was formed.

8. A sheet (10) as claimed in any preceding Claim, wherein the proportion of sheet material which is subjected to plastic strain of 0.05 or more is at least 65%.

9. A sheet (10) as claimed in any preceding Claim,

wherein the base gauge (G) is 2mm or greater.

10. A sheet (10) as claimed in Claim 9, having a pitch (P) of less than 26mm.

11. A sheet (10) as claimed in any preceding Claim, wherein the pitch (P) between adjacent depressions (12) or between adjacent projections (11) in each row (R12, R13) is between 2.5 and 13 times the base gauge (G).

12. A method of forming sheet material (17), the method comprising providing a sheet material (17) having a base gauge (G), providing a pair of opposed tools (18, 19) having rows of teeth (30) on their outer surface, placing the sheet material (17) between the tools (18, 19) and moving the tools (18, 19) such that rounded sheet engaging surfaces of the teeth (30) on one tool (18) urge portions of the sheet material (17) into gaps between the teeth (30) on the other tool (19) to form projections (11) on both surfaces of the sheet material (17), **characterised in that** the relative positions of the projections (11) and corresponding depressions (12) on the surfaces is such that lines drawn on a surface of the sheet (10) between adjacent rows (R12) of projections (12) are non-rectilinear, and **in that** the projections have a substantially continuous region of peak plastic strain (PP) at or about their apex and are thinned by no more than 25% of its base gauge (G).

13. A method as claimed in Claim 12, comprising urging the material (17) such that the apex or peak of the projections (11) are free from contact with the other tool (19) during forming.

14. A method as claimed in Claim 12 or Claim 13, comprising subjecting the sheet material (17) to a plastic strain of 0.05 or more across at least 65% of the formed area thereof.

15. A method as claimed in any one of Claims 12 to 14, wherein the clearance between the teeth (30) on one tool (18) and the teeth (30) on the other tool (19) during forming is at least 1.1 times the base gauge (G) of the plain sheet material (17).

Patentansprüche

1. Kaltgewalztes Blech (10), das auf beiden Seiten Reihen (R12) von Vorsprüngen (1) und Reihen (R13) von Vertiefungen (12) aufweist, wobei die Vorsprünge (11) auf einer Oberfläche den Vertiefungen (11) auf der anderen Oberfläche entsprechen, wobei die relativen Positionen der Vorsprünge (11) und der Vertiefungen (12) zueinander derart sind, dass Linien, die auf einer Oberfläche des Blechs (10) zwischen benachbarten Reihen (R12) von Vorsprüngen und Vertiefungen (12) gezogen sind, nicht geradlinig sind, und wobei das Blech (10) ein Basiskaliber (G) hat, **dadurch gekennzeichnet, dass** jeder Vorsprung (11) einen im Wesentlichen durchgehenden Bereich von plastischer Spitzenverformung (PP) an oder etwa an seinem Scheitel aufweist und um nicht auf mehr als 25 % des Grundkalibers (G) verdünnt ist.

2. Blech (10) nach Anspruch 1, bei dem die Basis jeder Vertiefung (12) zwei oder mehr unterschiedliche Krümmungsradien aufweist.

3. Blech (10) nach Anspruch 1 oder 2 , bei dem die Basis jeder Vertiefung (12) einen ersten Radius in einer ersten Richtung und einen zweiten Radius in einer zweiten Richtung entlang der Länge des Blechmaterials (10) enthält, wobei die erste Richtung sich von der zweiten Richtung unterscheidet, und wobei der Krümmungsradius entlang dem ersten Radius sich von dem Krümmungsradius entlang dem zweiten Radius unterscheidet.

4. Blech (10) nach einem vorhergehenden Anspruch, bei dem die Teilung (pitch) (P) zwischen benachbarten Vertiefungen (12) oder zwischen benachbarten Vorsprüngen (11) in jeder Reihe (R12, R13) wenigstens 2,5mal der des oder einem Krümmungsradius entlang dem oder einem ersten Radius entspricht.

5. Blech (10) nach Anspruch 4, bei dem die Teilung (P) zwischen 2,5 und 3,9mal der des Krümmungsradius entlang dem ersten Radius beträgt.

6. Blech (10) nach einem vorhergehenden Anspruch, bei dem der oder ein Krümmungsradius wenigsten gleich dem Basiskaliber (G) ist.

7. Blech (10) nach einem vorhergehenden Anspruch, bei dem die Amplitude (A) des Bleches (10) zwischen 1,5 und 4mal der des Basiskalibers (G) des Materials (17) liegt, aus dem das Blech (10) geformt ist.

8. Blech (10) nach einem vorhergehenden Anspruch, bei dem der Anteil des Blechmaterials , das einer plastischen Verformung von 0.05 oder mehr unterworfen ist, wenigstens 65 % beträgt.

9. Blech (10) nach einem vorhergehenden Anspruch, bei den das Basiskaliber (G) 2 mm oder größer ist.

10. Blechs (10) nach Anspruch 9, welches eine Teilung (P) von weniger als 26 mm aufweist.

11. Blech (10) nach einem vorhergehenden Anspruch, bei dem die Teilung (P) zwischen benachbarten Vertiefungen (12) oder zwischen benachbarten Vorsprüngen (11) in jeder Reihe (R12, R13) zwischen 2,5 und 13mal der des Basiskalibers (G) beträgt.

12. Verfahren zur Formung von Blechmaterial (17), wobei das Verfahren Folgendes umfasst: Bereitstellen eines Blechmaterials (17), das ein Basiskaliber (G) aufweist, Bereitstellen eines Paars von gegenüberliegenden Werkzeugen (18, 19), welche Reihen von Zähnen (30) auf ihrer äußeren Oberfläche aufweisen, Einbringen des Blechmaterials (17) zwischen die Werkzeuge (18, 19) und Bewegen der Werkzeuge (18, 19), derart, dass abgerundete das Blech erfassende Oberflächen der Zähne (30) an einem Werkzeug (18) Bereiche des Blechmaterials (17) in Lücken zwischen den Zähnen (30) auf dem anderen Werkzeug (19) eindrücken, um Vorsprünge (11) auf beiden Oberflächen des Blechmaterials (17) zu bilden, **dadurch gekennzeichnet, dass** die relativen Positionen der Vorsprünge (11) und der entsprechenden Vertiefungen (12) auf den Oberflächen derart ausgebildet sind, dass Linien, die auf einer Oberfläche des Blechs (10) zwischen benachbarten Reihen (R12) von Vorsprüngen (12) nicht geradlinig sind, und dass die Vorsprünge einen im Wesentlichen durchgängigen Bereich der plastischen Verformung (PP) bei oder um ihren Scheitel aufweisen und um nicht mehr als 25 % ihres Basiskalibers (G) verdünnt sind.

13. Verfahren nach Anspruch 12, welches das Drücken den Materials (17) umfasst, derart, dass der Scheitel oder die Spitze der Vorsprünge (11) während der Formung keinen Kontakt mit dem anderen Werkzeug (19) erhält.

14. Verfahren nach Anspruch 12 oder 13, welches das Unterwerfen des Blechmaterials (17) einer plastischen Verformung von 0.05 oder mehr über wenigstens 65 % ihrer verformten Fläche umfasst.

15. Verfahren nach einem der Ansprüche 12 - 14, bei dem der Freiraum zwischen den Zähnen (30) auf einem Werkzeug (18) und den Zähnen (30) auf dem anderen Werkzeug (19) während der Formung wenigstens 1.1mal dem des Basiskalibers (G) auf dem ebenen Blechmaterial (17) beträgt.

Revendications

1. Feuille (10) de matériau laminé à froid comportant sur ses deux surfaces des rangées (R12) de protubérances (11) et des rangées (R13) de creux (12), les protubérances (11) sur une surface correspondant aux creux (12) sur l'autre surface, les positions relatives des protubérances (11) et des creux (12) étant telles que des lignes dessinées sur une surface de la feuille (10) entre des rangées (R12) adjacentes de protubérances (12) sont non rectilignes, la feuille (10) ayant une jauge de base (G), **caractérisée en ce que** chaque protubérance (11) a une région sensiblement continue de déformation plastique crête (PP) au niveau ou autour de son sommet et est amincie de pas plus de 25 % de sa jauge de base (G).

2. Feuille (10) selon la revendication 1, dans laquelle la base de chaque creux (12) comprend deux rayons de courbure différents ou plus.

3. Feuille (10) selon la revendication 1 ou 2, dans laquelle la base de chaque creux (12) comprend un premier rayon dans une première direction, un deuxième rayon dans une deuxième direction le long de la longueur du matériau en feuille (10), la première direction étant différente de la deuxième direction, dans laquelle le rayon de courbure le long du premier rayon est différent du rayon de courbure le long du deuxième rayon.

4. Feuille (10) selon l'une quelconque des revendications précédentes, dans laquelle le pas (P) entre des creux (12) adjacents ou entre des protubérances (11) adjacentes dans chaque rangée (R12, R13) est égal à au moins 2,5 fois le ou un rayon de courbure le long du ou d'un premier rayon.

5. Feuille (10) selon la revendication 4, dans laquelle le pas (P) est entre 2,5 et 3,9 fois le rayon de courbure le long du premier rayon.

6. Feuille (10) selon l'une quelconque des revendications précédentes, dans laquelle le ou un rayon de courbure est au moins égal à la jauge de base (G).

7. Feuille (10) selon l'une quelconque des revendications précédentes, dans laquelle l'amplitude (A) de la feuille (10) est entre 1,5 et 4 fois la jauge de base (G) du matériau (17) à partir duquel la feuille (10) a été formée.

8. Feuille (10) selon l'une quelconque des revendications précédentes, dans laquelle la proportion de matériau en feuille qui est soumise à une déformation plastique de 0,05 ou plus est au moins de 65 %.

9. Feuille (10) selon l'une quelconque des revendications précédentes, dans laquelle la jauge de base (G) est égale à 2 mm ou plus.

10. Feuille (10) selon la revendication 9, ayant un pas (P) inférieur à 26 mm.

11. Feuille (10) selon l'une quelconque des revendications précédentes, dans laquelle le pas (P) entre des creux (12) adjacents ou entre des protubérances

(11) adjacentes dans chaque rangée (R12, R13) est entre 2,5 et 13 fois la jauge de base (G).

12. Procédé de formage d'un matériau en feuille (17), le procédé consistant à fournir un matériau en feuille (17) ayant une jauge de base (G), fournir une paire d'outils (18, 19) opposés comportant des rangées de dents (30) sur leur surface extérieure, placer le matériau en feuille (17) entre les outils (18, 19) et déplacer les outils (18, 19) de sorte que les surfaces arrondies de mise en prise avec la feuille des dents (30) sur un outil (18) poussent des parties du matériau en feuille (17) dans des espaces entre les dents (30) sur l'autre outil (19) pour former des protubérances (11) sur les deux surfaces du matériau en feuille (17), **caractérisé en ce que** les positions relatives des protubérances (11) et des creux (12) correspondants sur les surfaces sont telles que des lignes dessinées sur une surface de la feuille (10) entre des rangées (R12) adjacentes de protubérances (12) sont non rectilignes et que les protubérances comportent une région sensiblement continue de déformation plastique crête (PP) au niveau de ou autour de leur sommet et sont amincies de pas plus de 25 % de leur jauge de base (G).

13. Procédé selon la revendication 12, consistant à pousser le matériau (17) de sorte que les sommets ou les crêtes des protubérances (11) ne soient pas en contact avec l'autre outil (19) pendant le formage.

14. Procédé selon la revendication 12 ou la revendication 13, consistant à soumettre le matériau en feuille (17) à une déformation plastique de 0,05 ou plus sur au moins 65 % de la zone formée de celui-ci.

15. Procédé selon l'une quelconque des revendications 12 à 14, dans lequel le dégagement entre les dents (30) sur un outil (18) et les dents (30) sur l'autre outil (19) pendant le formage est égal à au moins 1,1 fois la jauge de base (G) du matériau en feuille (17) simple.

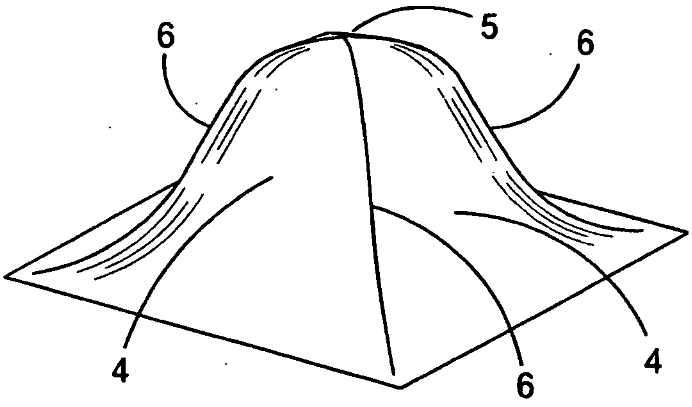

FIGURE 1 PRIOR ART

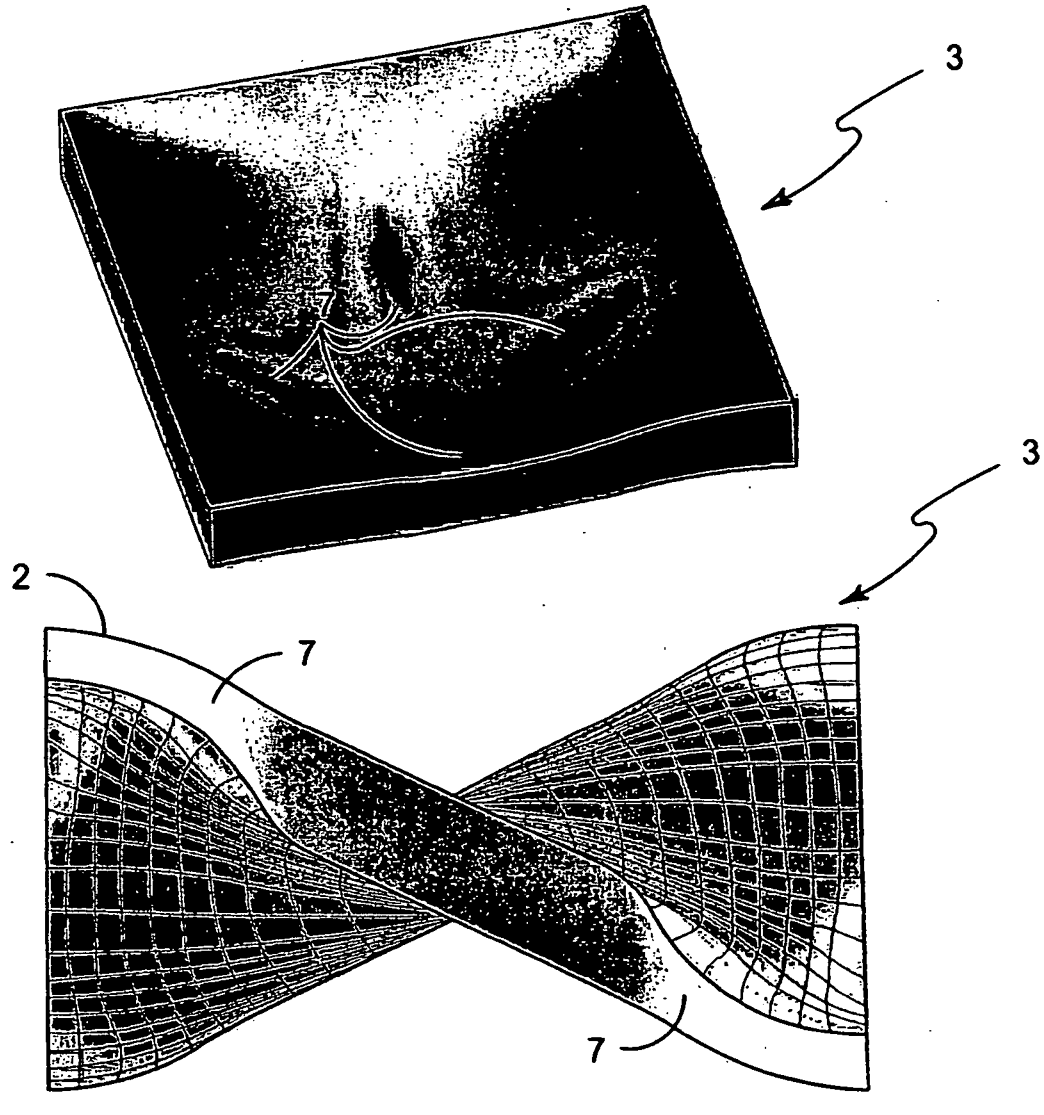

FIGURE 2 PRIOR ART

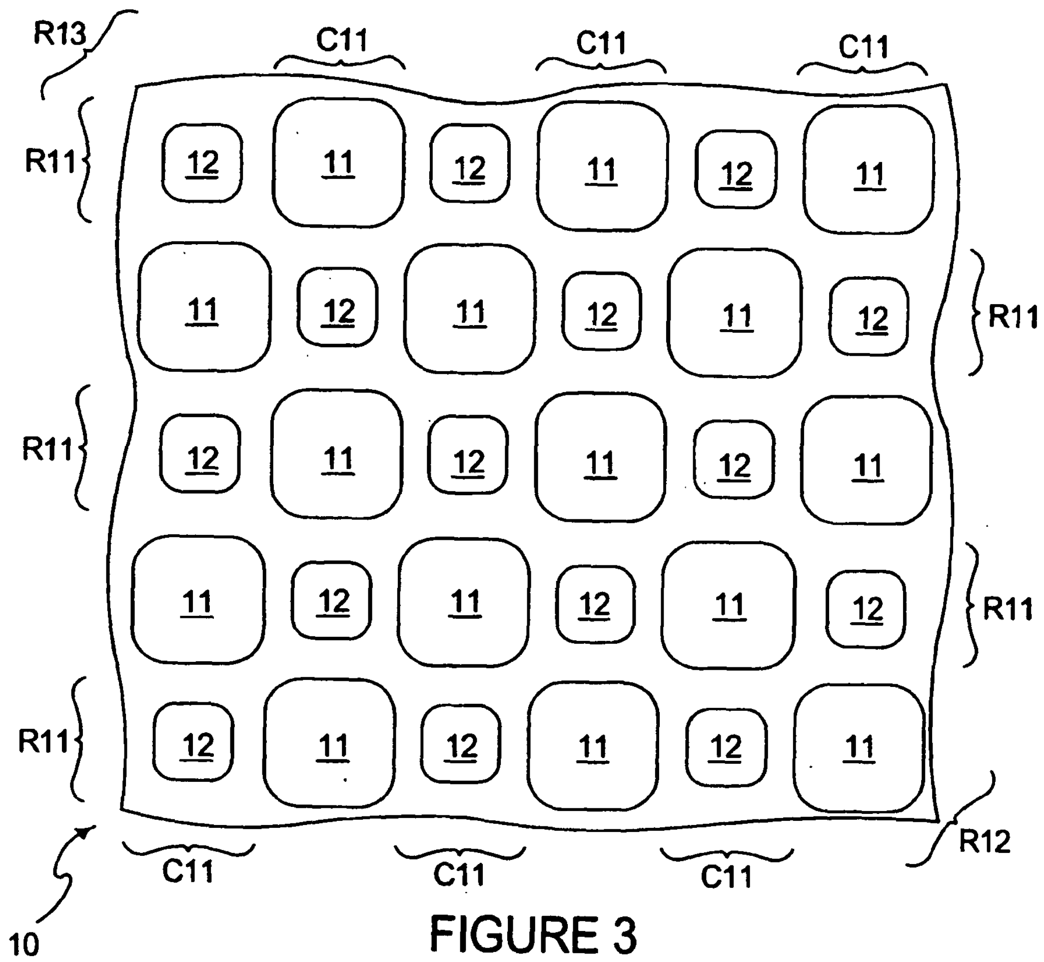

FIGURE 3

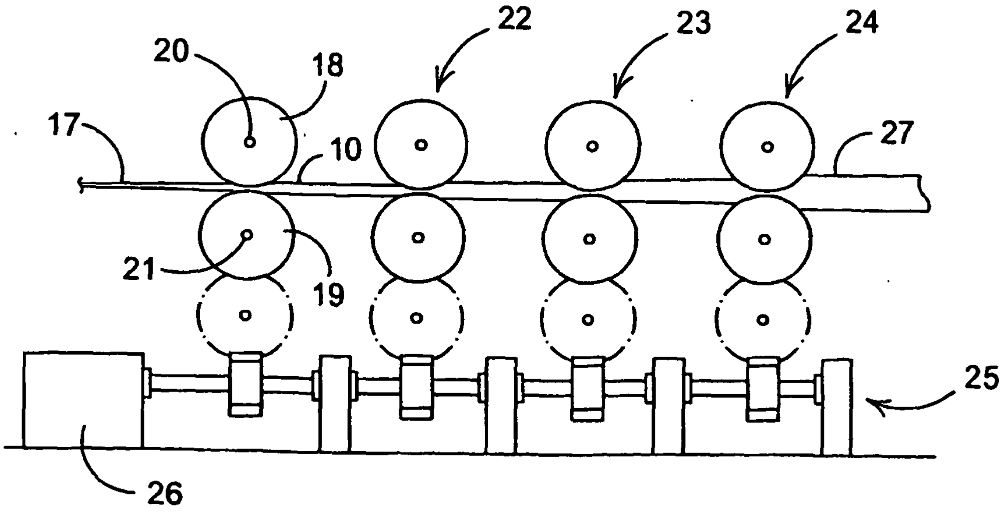

FIGURE 4

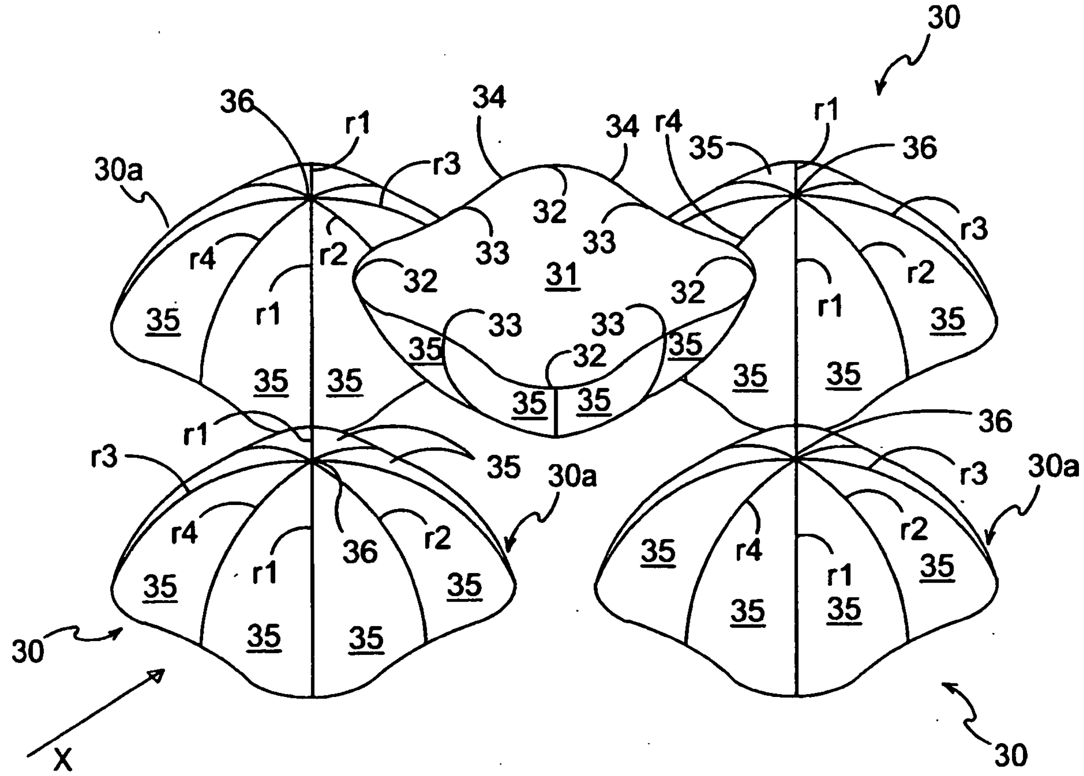

FIGURE 5

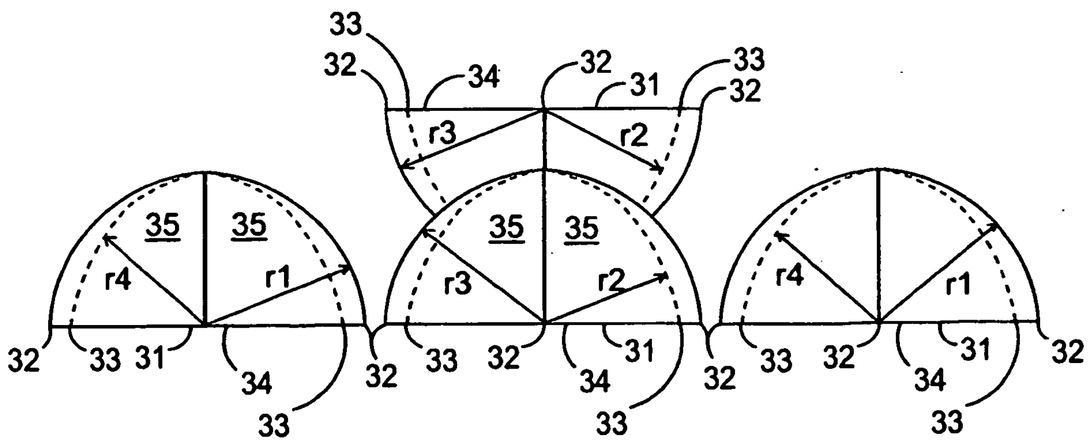

FIGURE 6

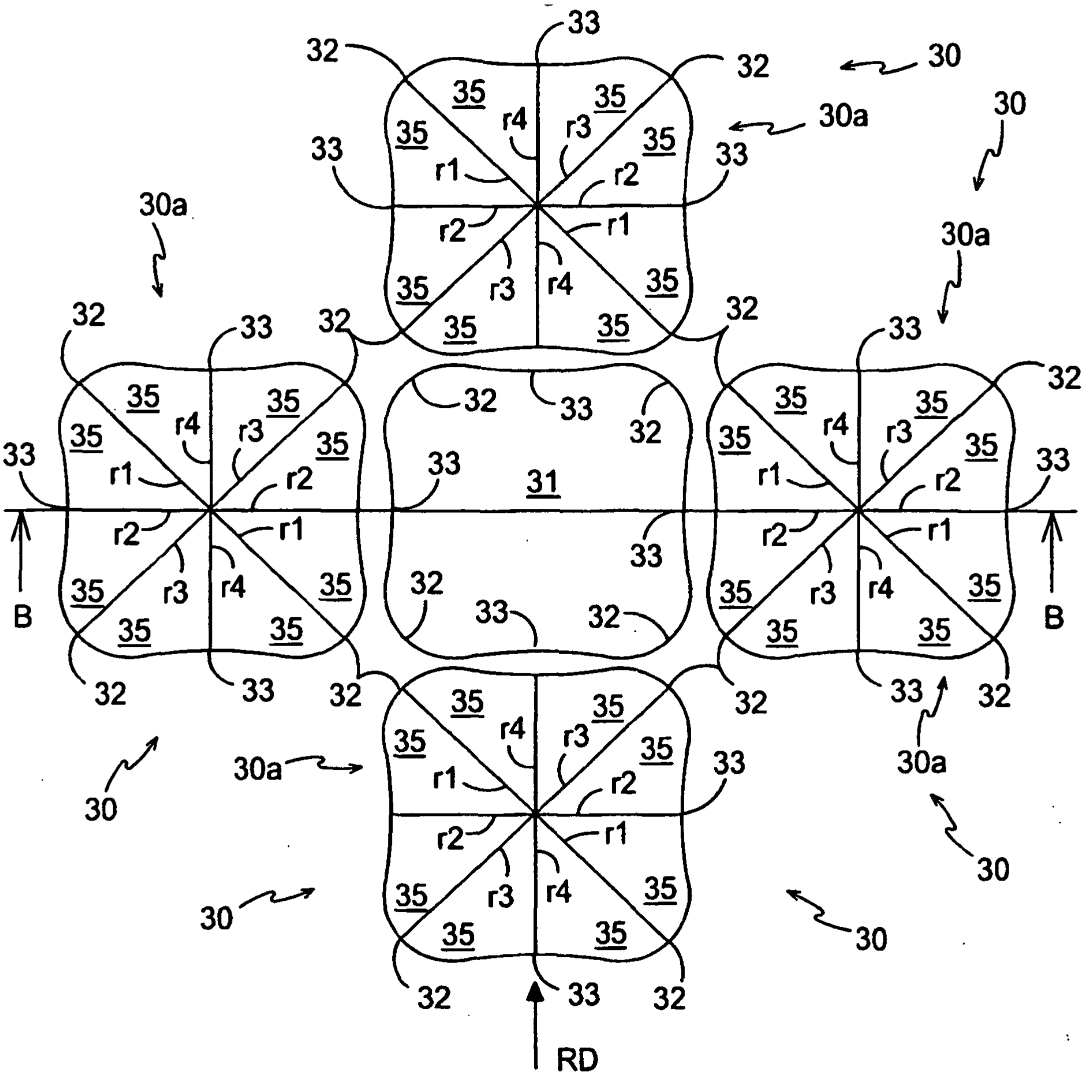

FIGURE 7

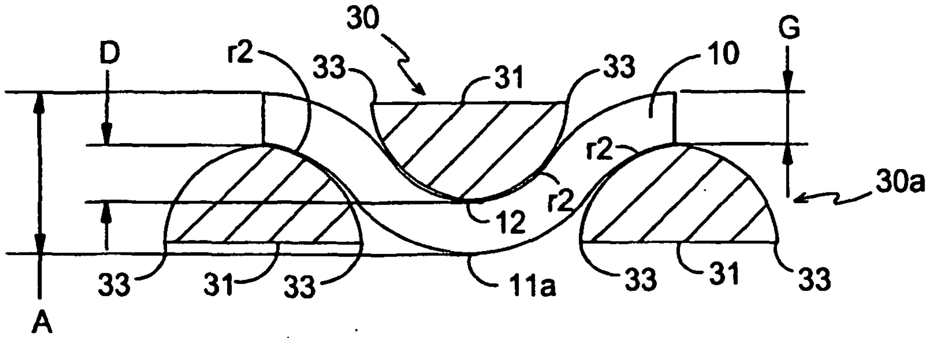

FIGURE 8

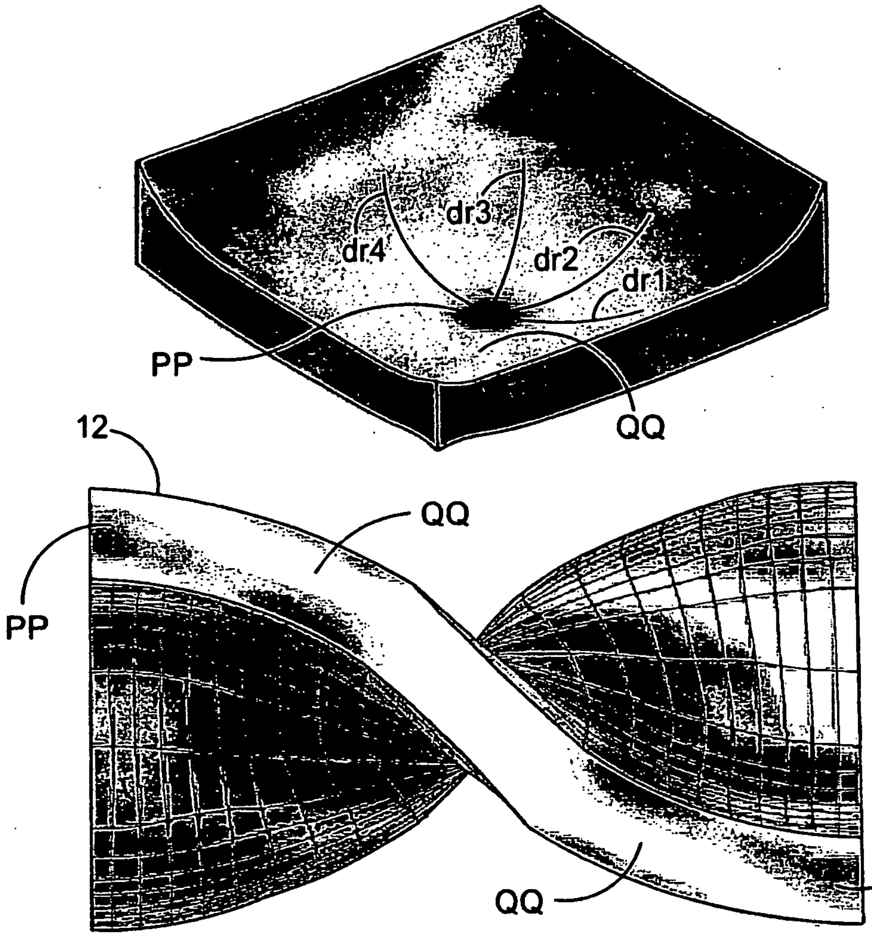

FIGURE 8A

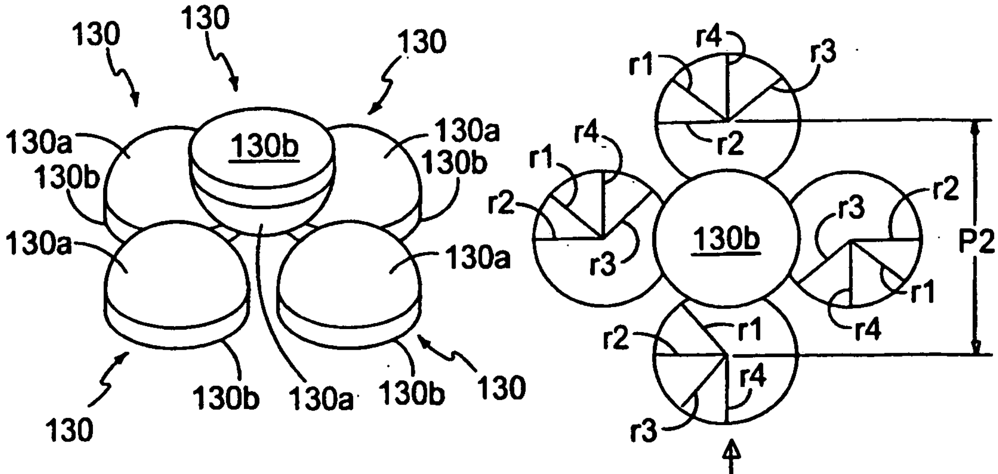

FIGURE 9

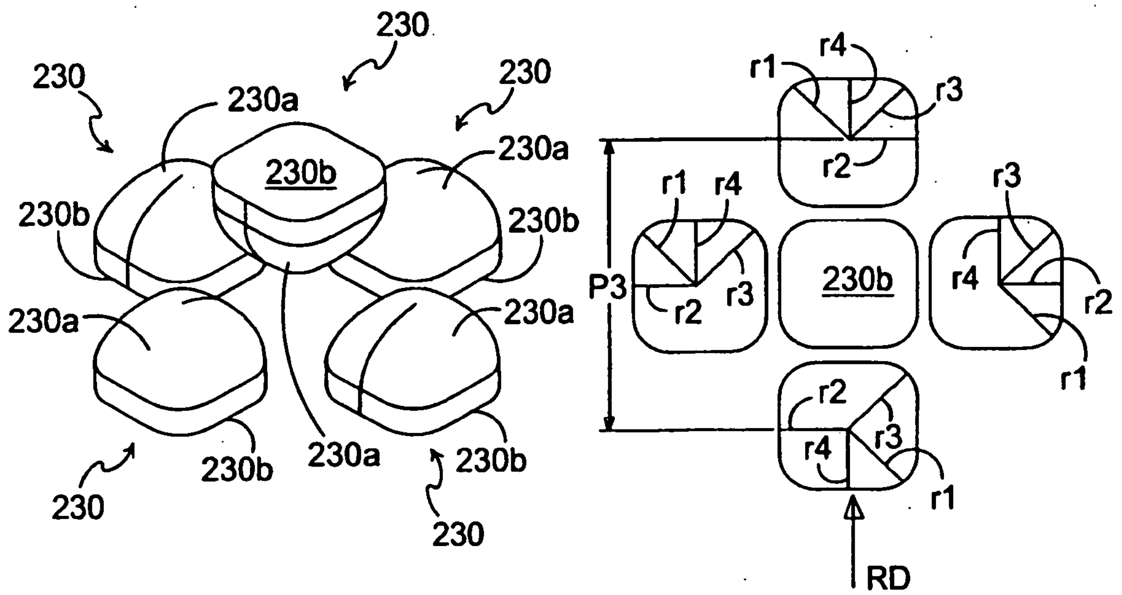

FIGURE 10

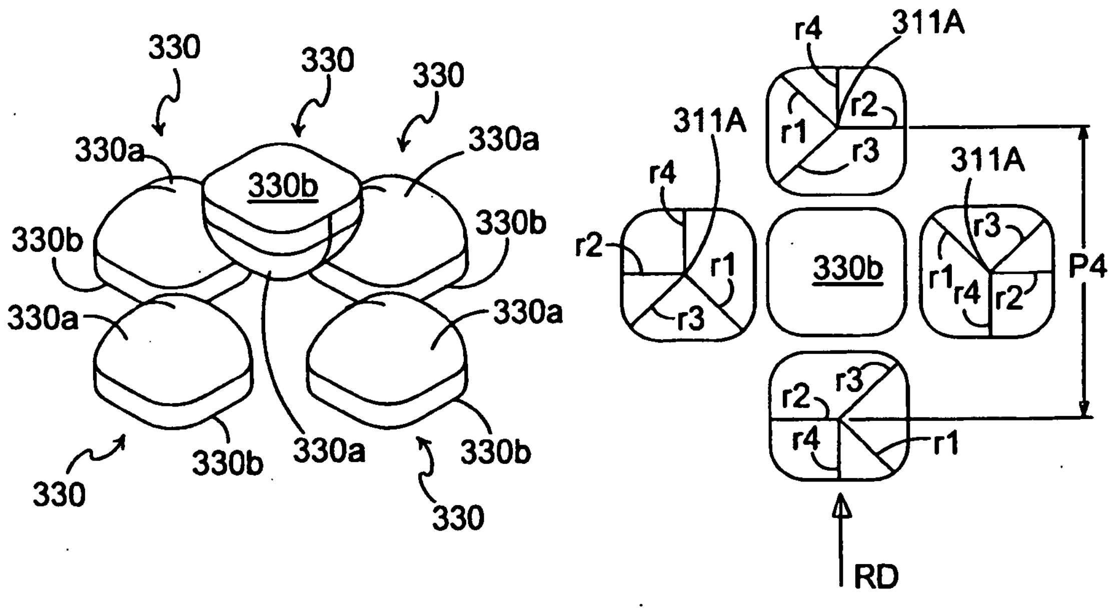

FIGURE 11

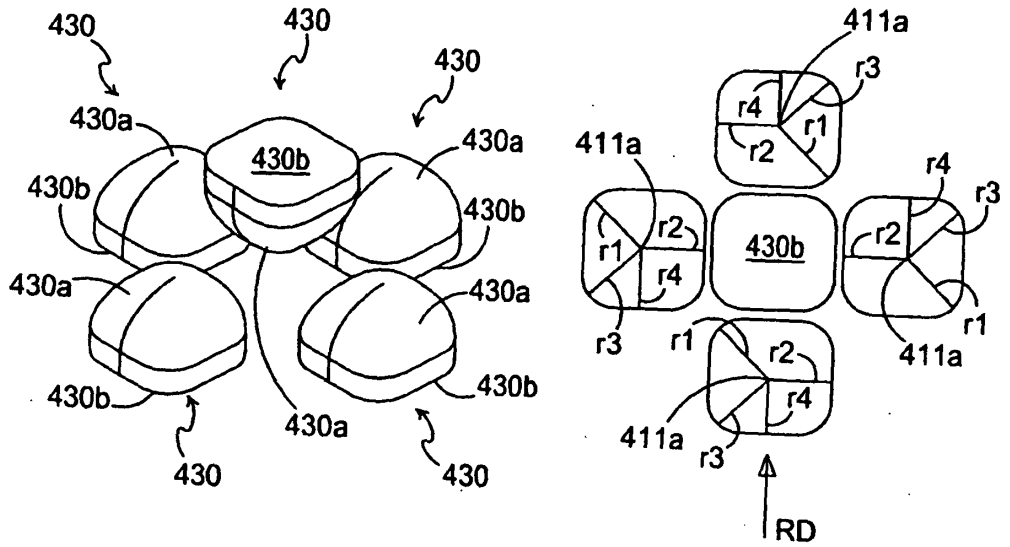

FIGURE 12

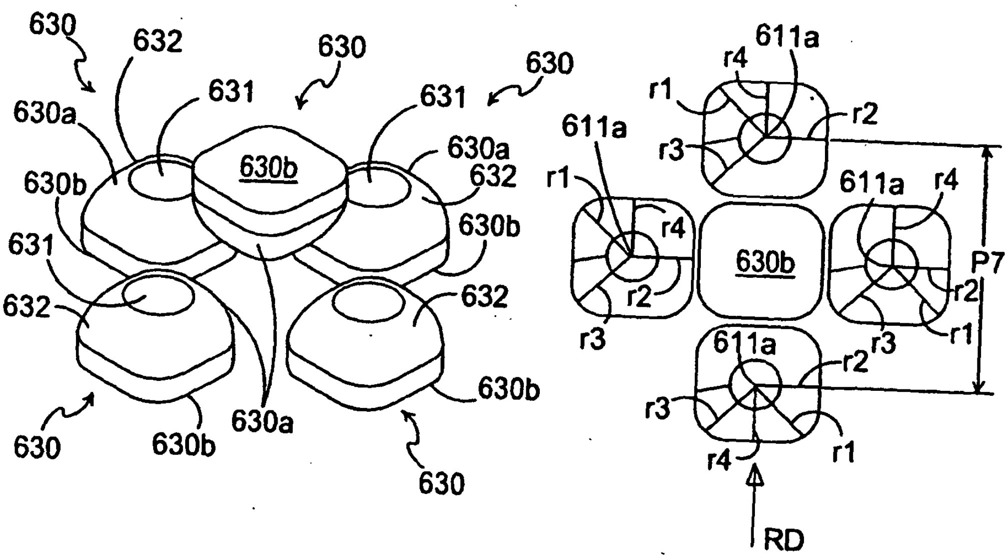

FIGURE 13

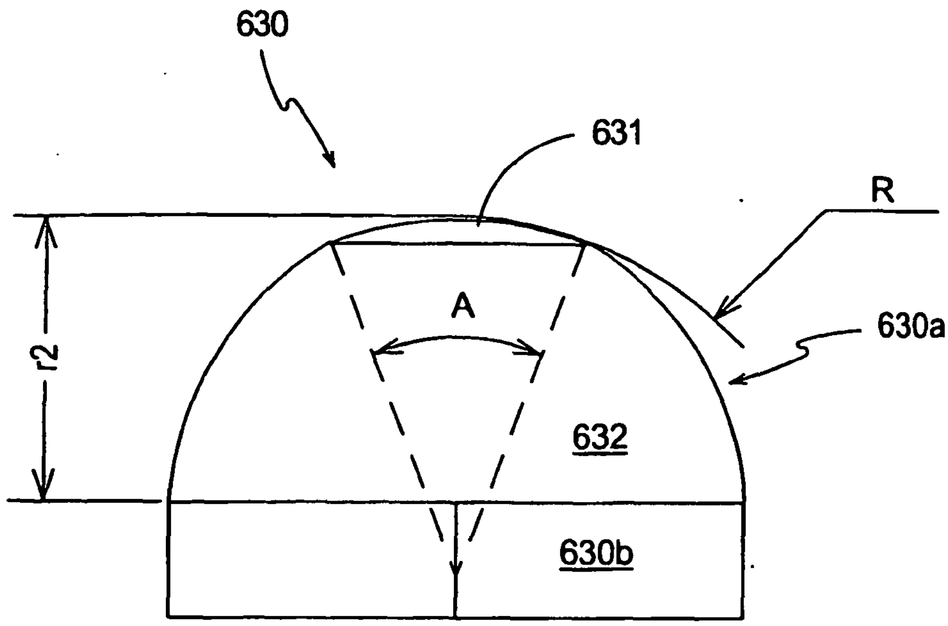

FIGURE 14A

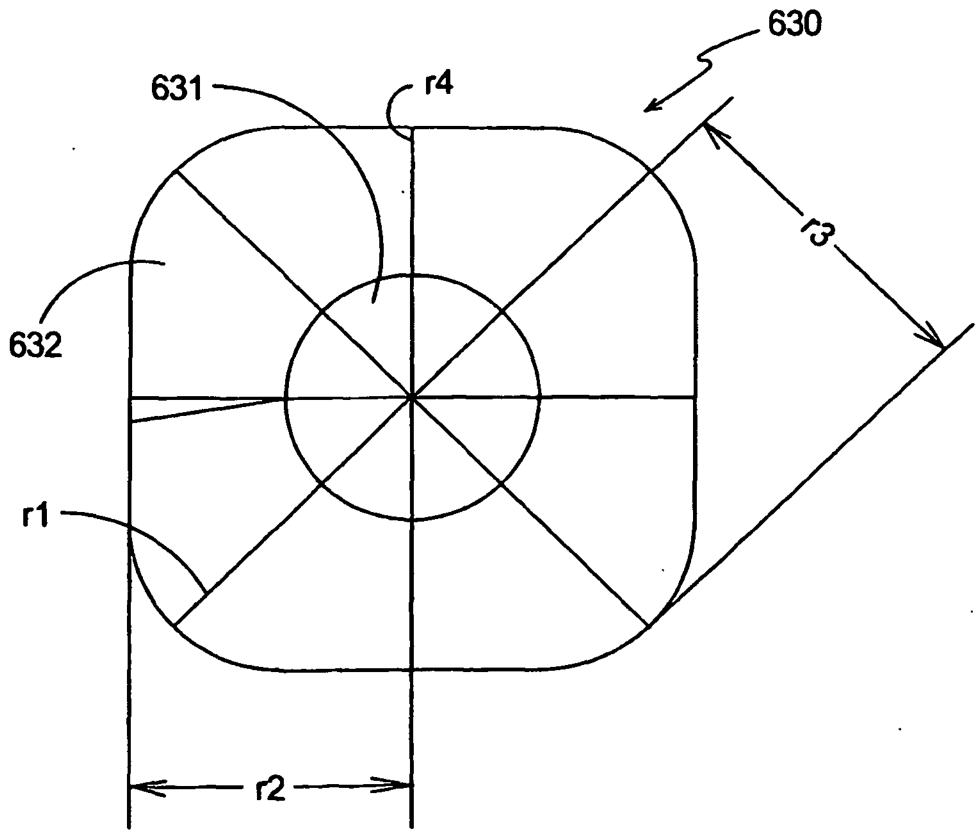

FIGURE 14B

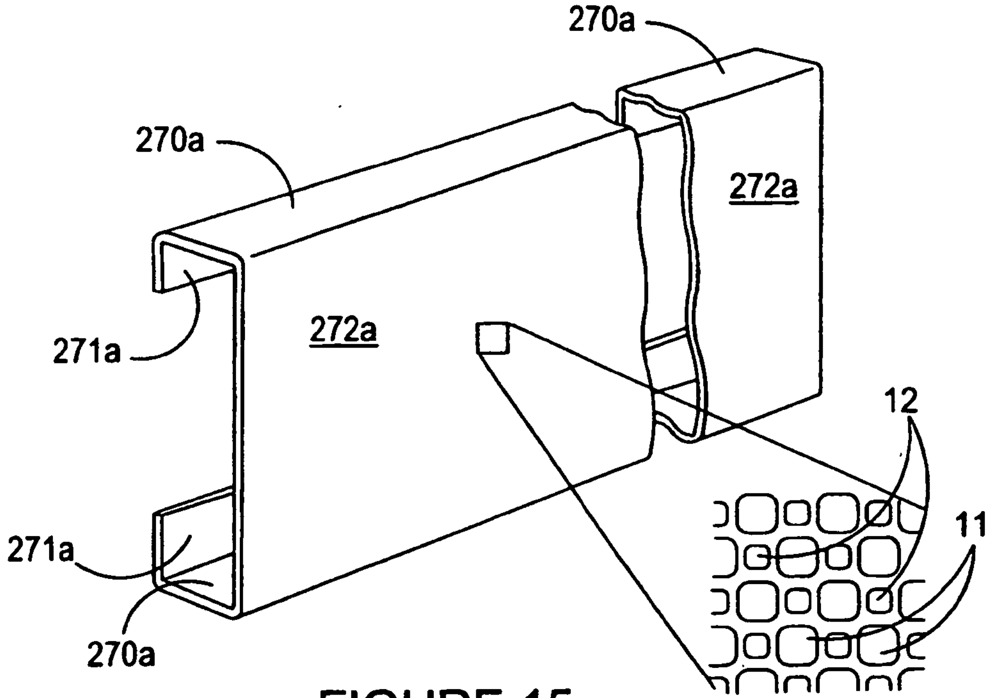

FIGURE 15

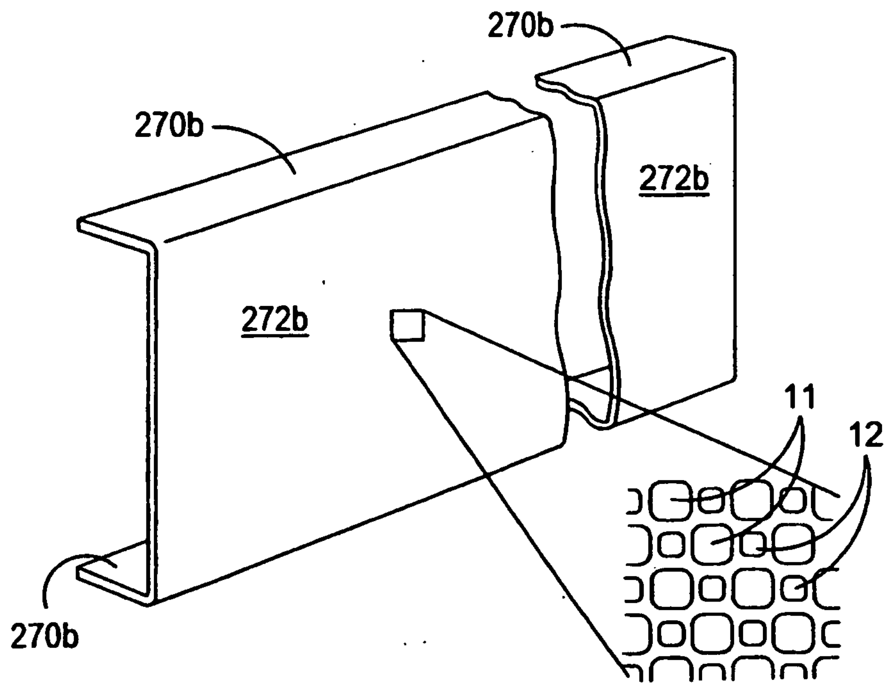

FIGURE 16

REFERENCES CITED IN THE DESCRIPTION

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- EP 0891234 A **[0041]**
- WO 8203347 A **[0102]**