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EP 0144870 A EP 0020829 A US 4025996 A
US 3992835 A

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(54) Plastic strain hardened sheet material and a method of forming such material

(57) Ductile sheet material has part-spheroid or ellipsoidal interconnecting projections 7 and depressions 3, disposed longitudinally and laterally over a region of both surfaces of the material, so that any cross section view of the region is sinuous in appearance.

Two opposing parts 27 and 28 of a compression tool have arranged in rows on their surface, part-spherical or ellipsoidal formers so that when opposing parts are engaged a tensile force is applied to both sides of sheet material simultaneously.

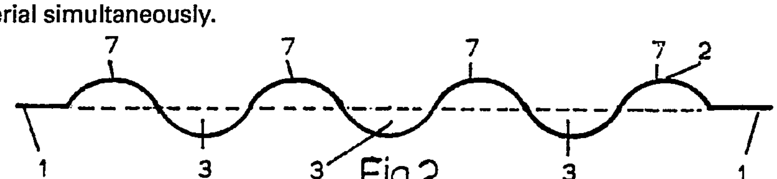

Fig 2

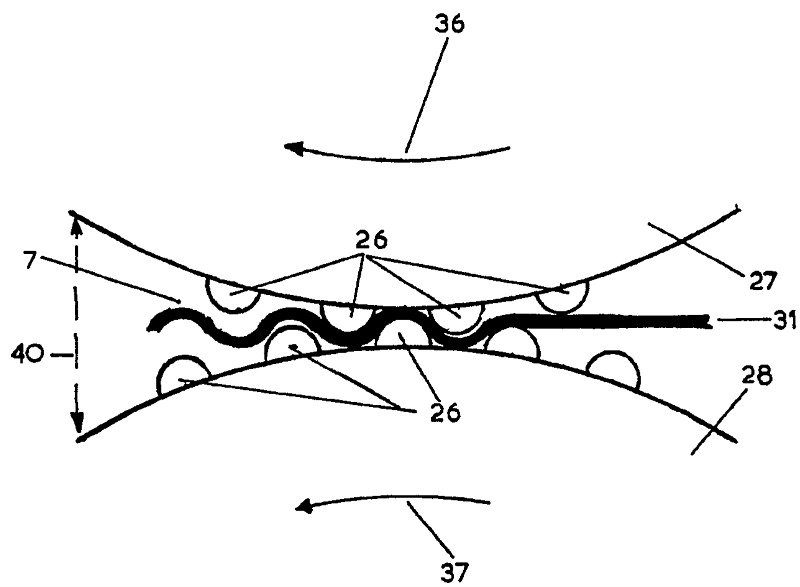

Fig14

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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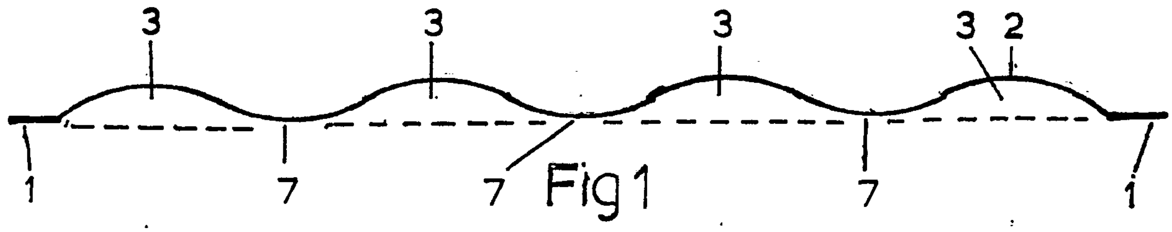

Fig 1

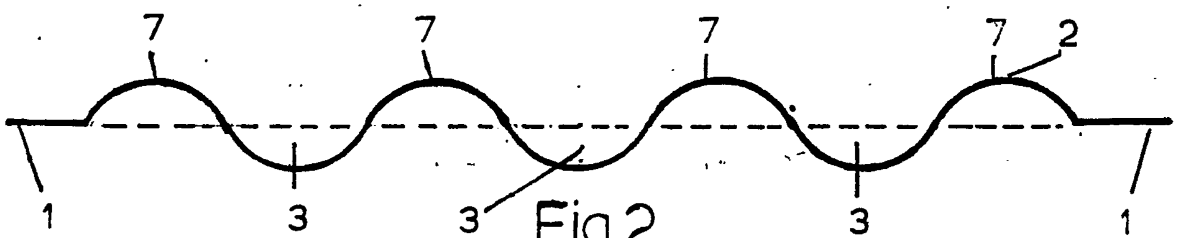

Fig 2

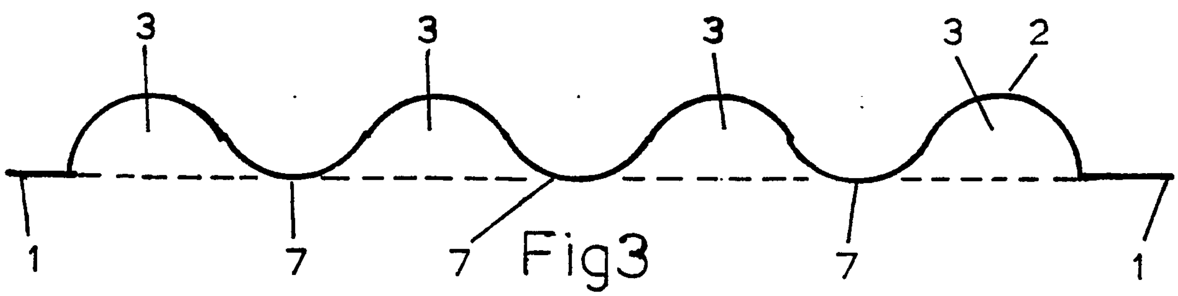

Fig 3

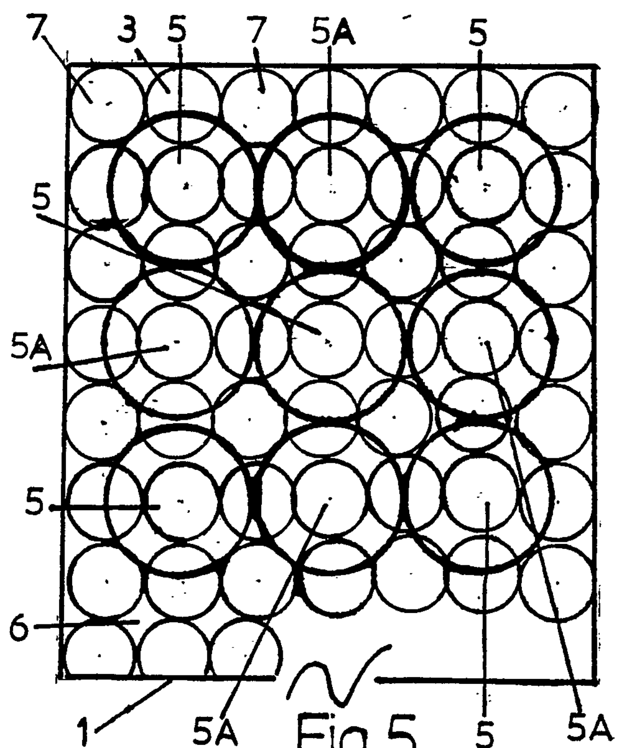

Fig 5

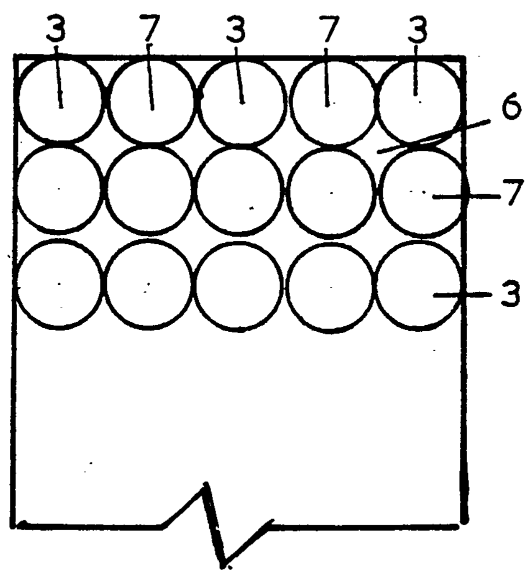

Fig 4

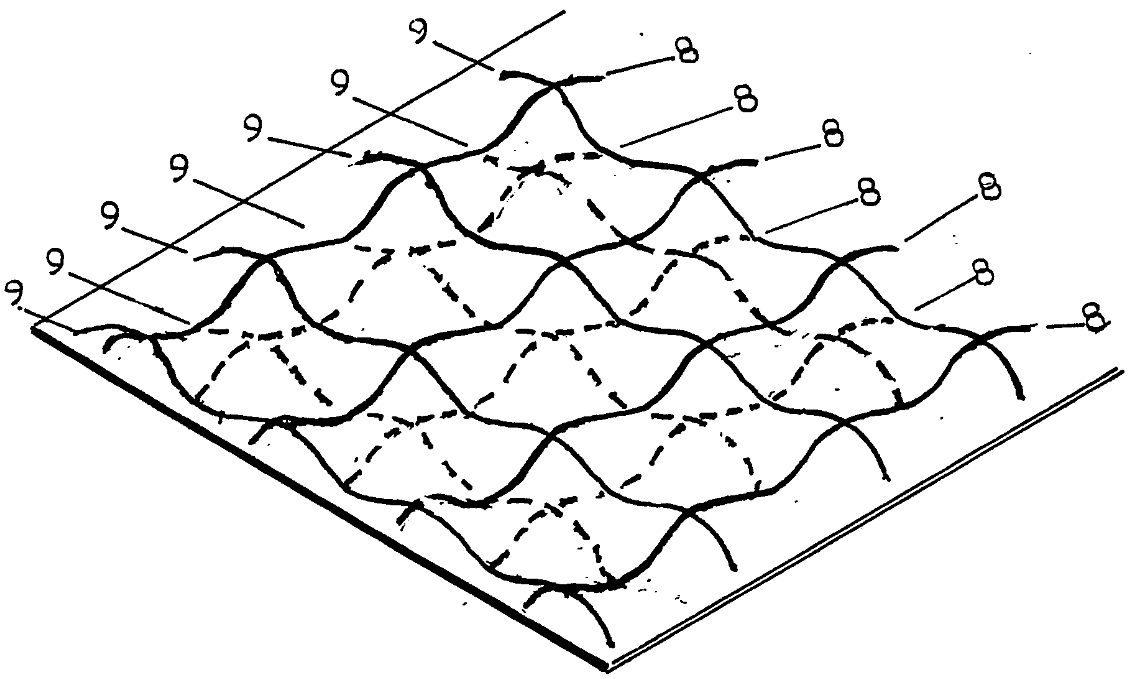

Fig 6

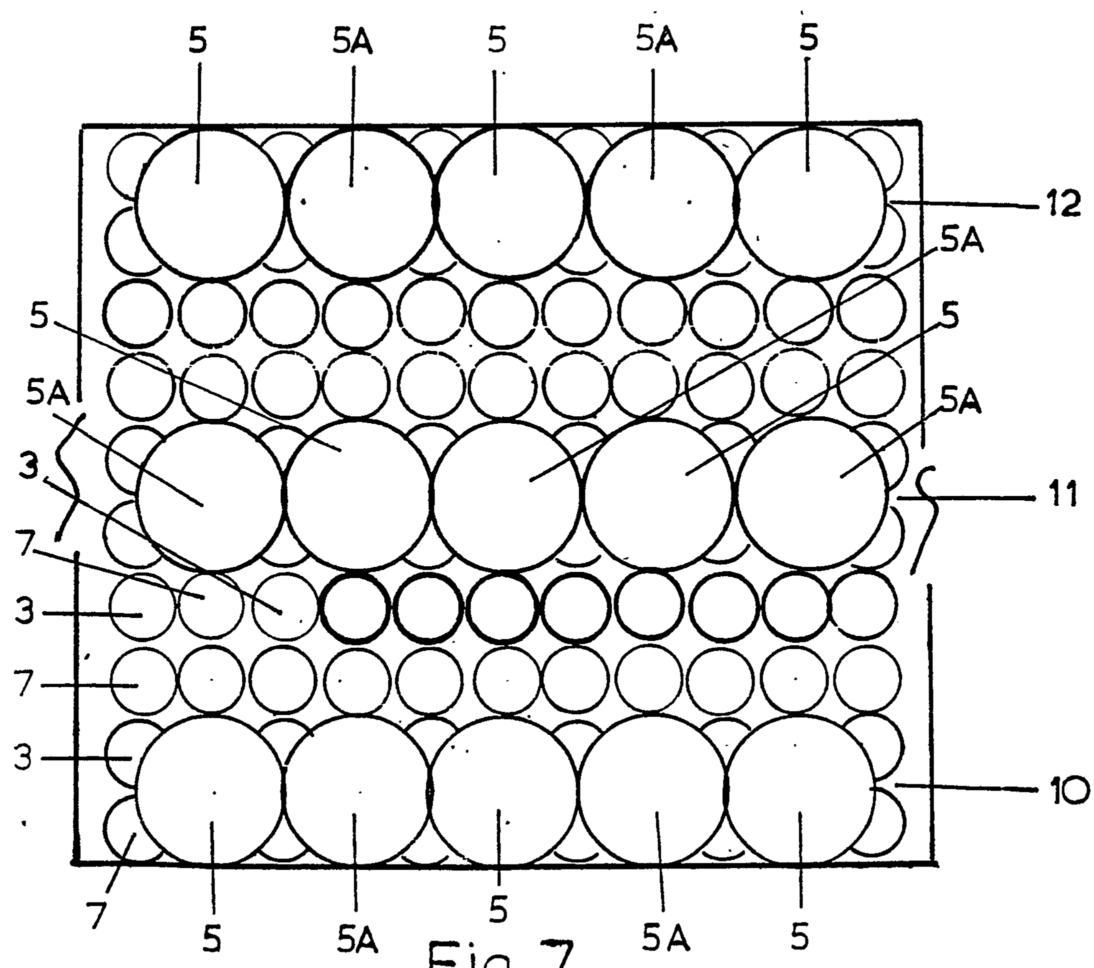

Fig 7

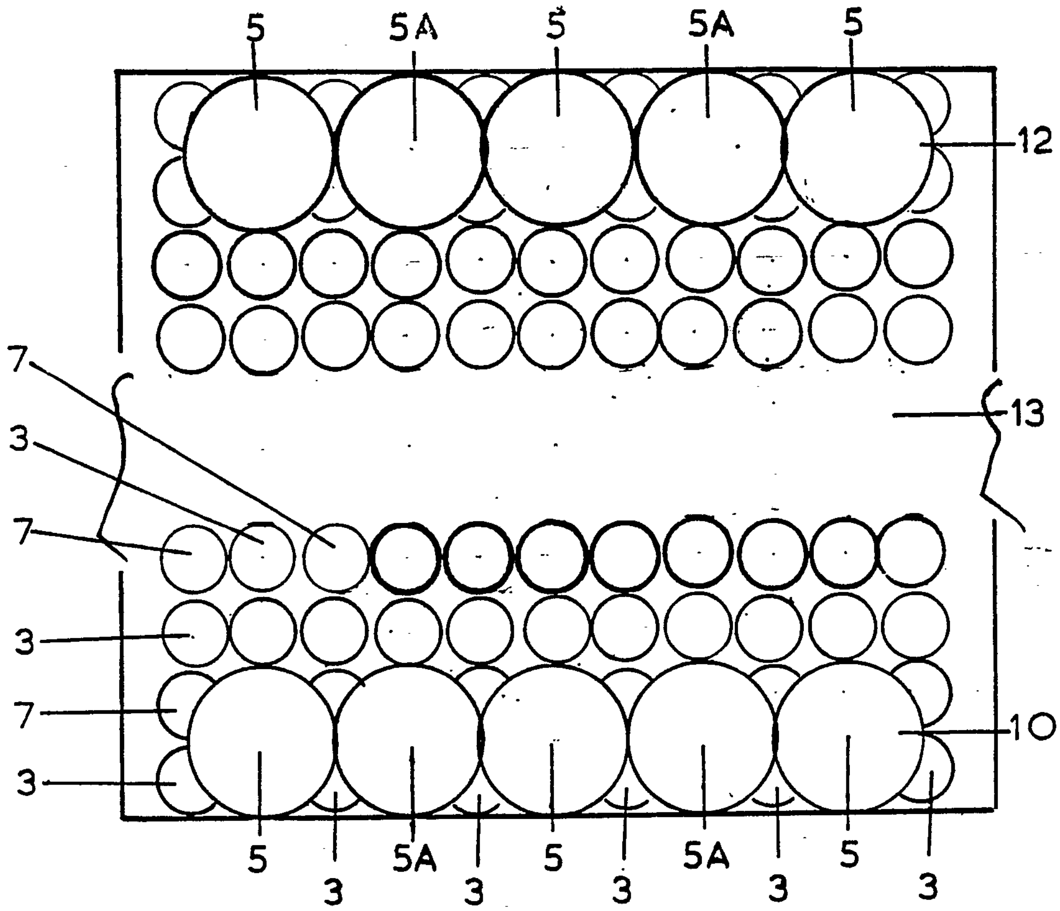

Fig 8

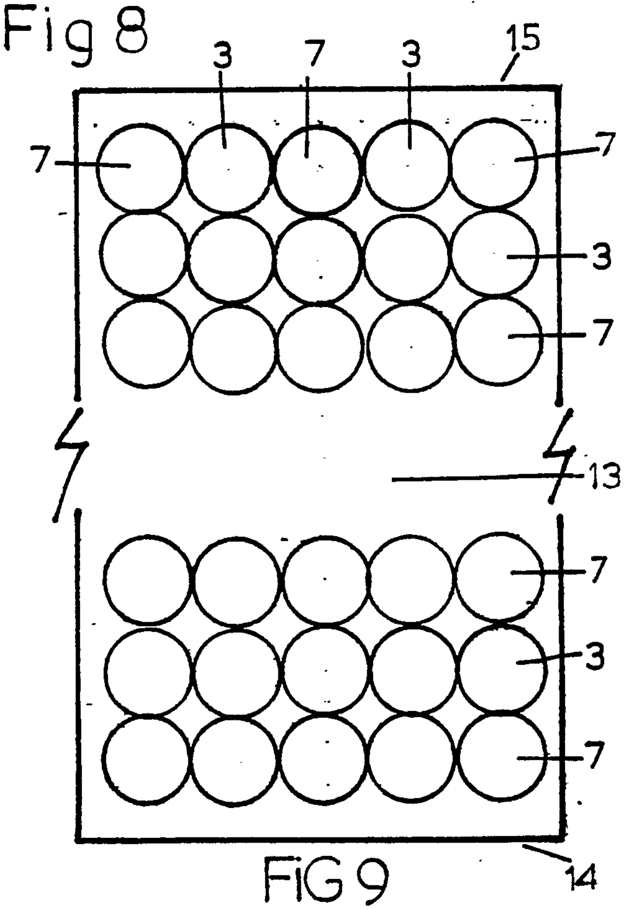

FIG 9

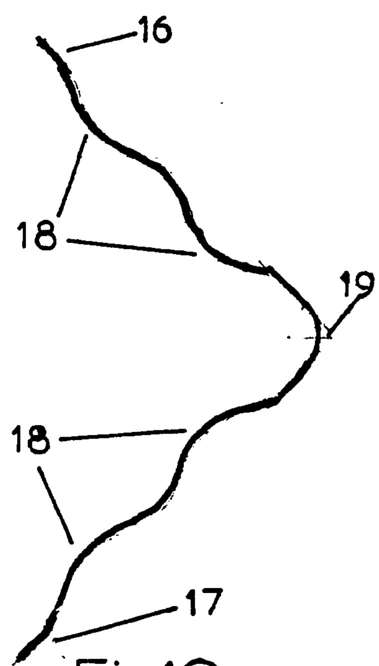

Fig 10

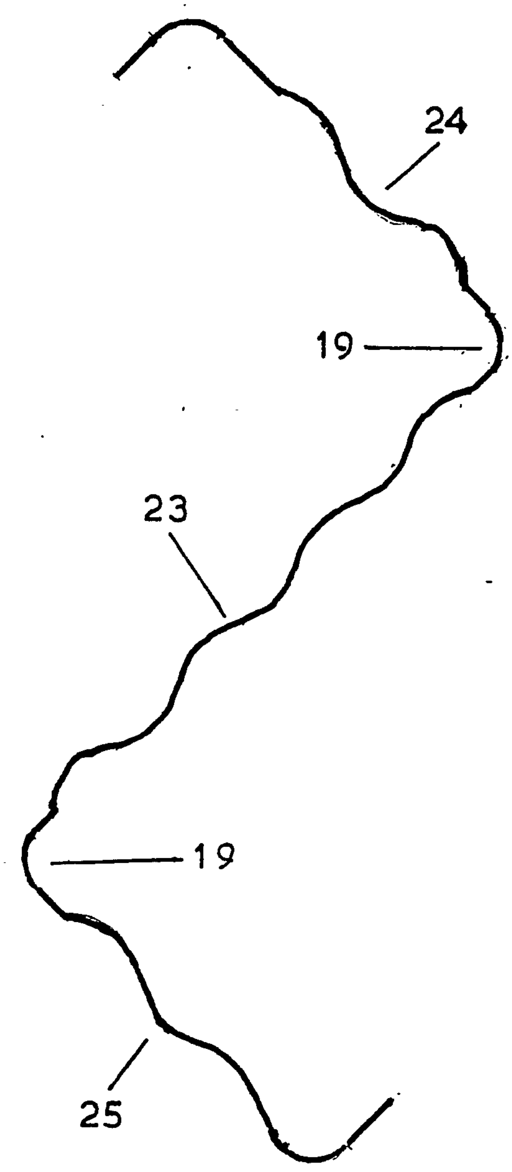

Fig 12

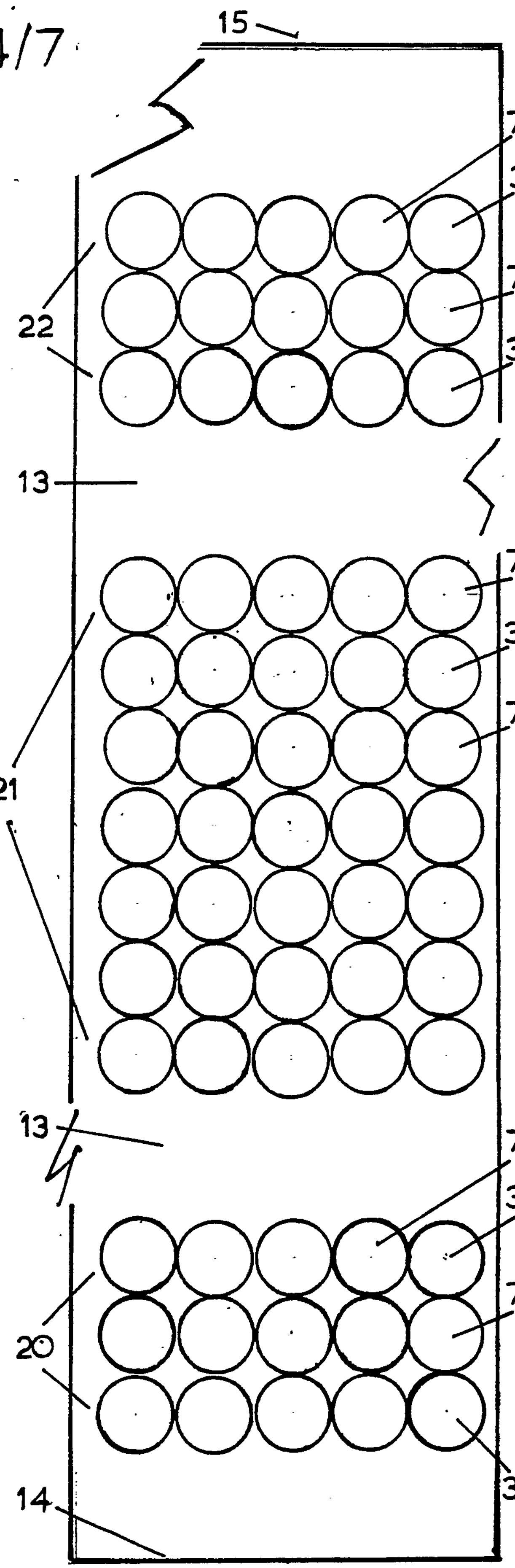

Fig 11

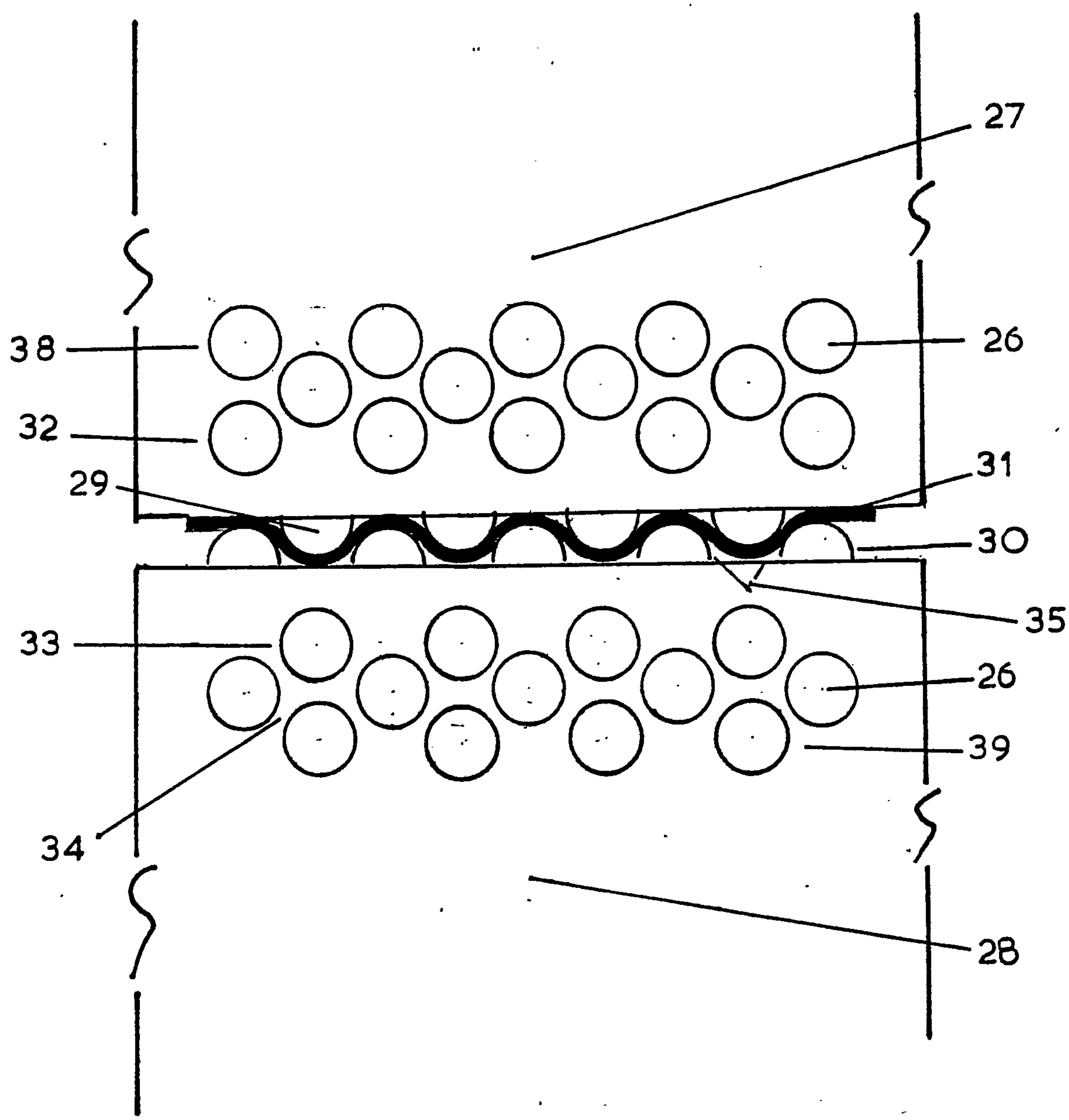

Fig13

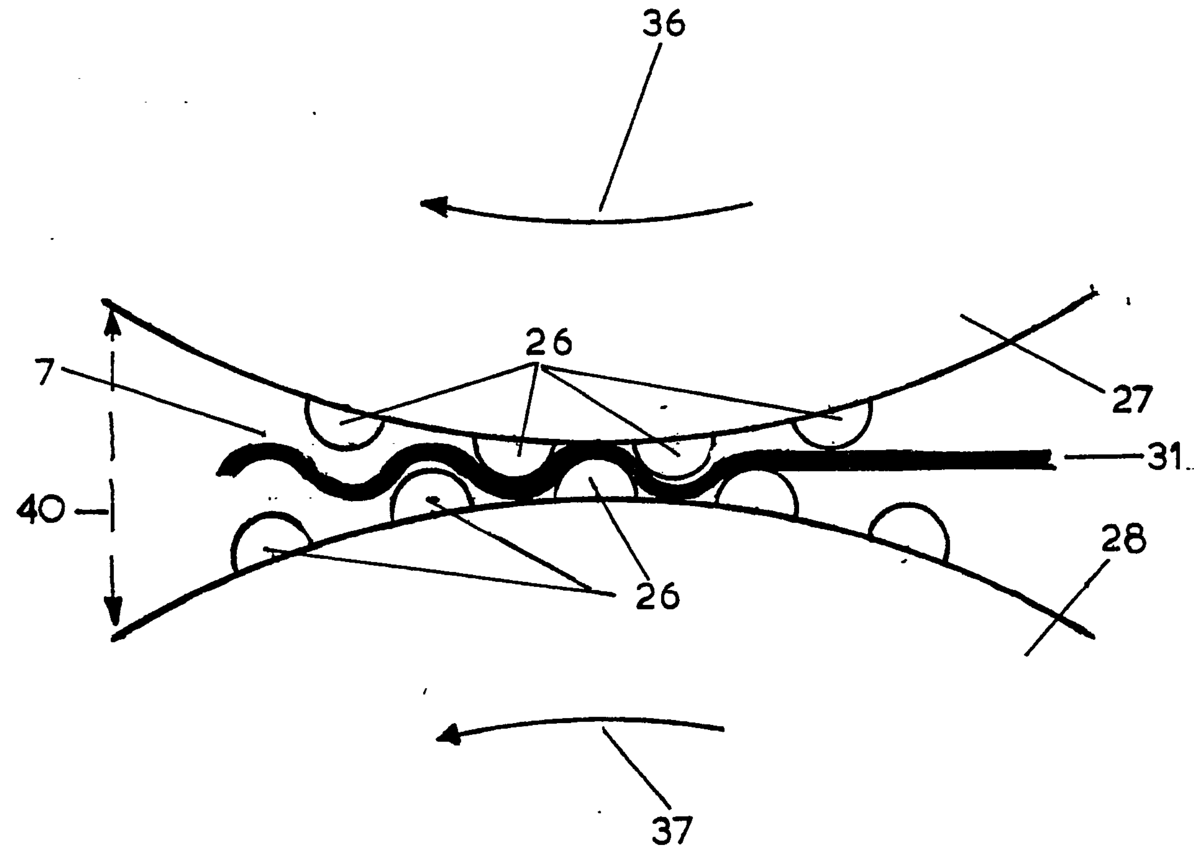

Fig14

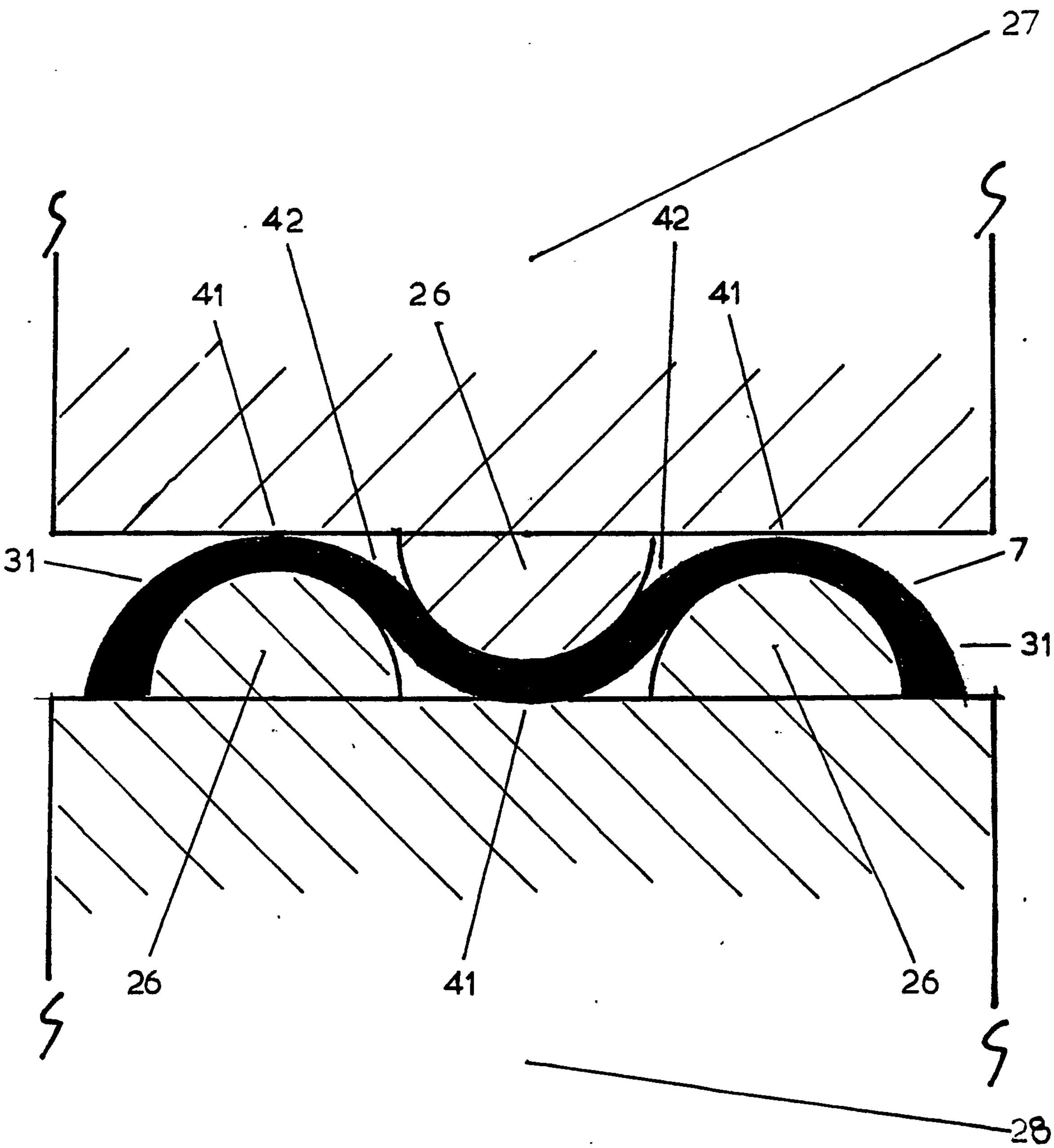

Fig 15

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PLASTIC STRAIN HARDENED SHEET MATERIAL AND A METHOD OF FORMING SUCH MATERIAL

This invention relates to ductile sheet material which has been subjected to a plastic strain hardening (also known as work hardening) process to increase its hardness and tensile strength. It also relates to a method of effecting the changed status of the sheet material.

The term "sheet material" is used generically to embrace generally flat sheets, flat strips, and coils of flat material, usually metal, which can be of indeterminate length, and have width and thickness dimensions limited only by the capacity of a cold rollform machine or power press through which the material is to be processed, and by the materials ductility and plasticity.

Generally but not exclusively, the sheet material will be ferrous or non-ferrous based, having known properties in terms of tensile, compressive, and sheer strength, plus plasticity. In the case of ferrous based metal sheets they can be of any steel, or alloy steel composition which is classified as ductile, and suitable for cold working.

It is known that the properties of sheet material, especially those concerned with hardness and tensile strength, can be increased in value by changing the cross-section configuration of the sheet by use of a cold forming process. By this is meant changing the surface profile of the material whilst retaining its generally planar configuration.

One known ductile sheet configuration includes press formed discrete trapezoidal shaped formations which are discontinuous in both longitudinal and transverse directions. A second known ductile sheet (as disclosed in G.B.-A-2,095,595) also includes discrete trapezoidal shaped formations which are roll formed, and are only discontinuous in a longitudinal direction of the material.

A disadvantage arising from forming discrete discontinuous trapezoidal projections is that the uninterrupted material interspersed between the projections experiences limited tensile improvement and as a result tends to form areas or lines of weakness in the sheet. A further disadvantage is that any protective or decorative surface coating (such as zinc in the case of pre-galvanised steel sheets) applied to the sheets prior to the formation of the projections may be rendered less efficient especially at the peripheral margins of each projection and depression. Inter-engaging male and female tools are used in the manufacturing processes of both known sheets to aggressively stretch form each projection and depression around a former which has up to five interconnecting planes defined by eight peripheral margins thereby subjecting any surface coating to a variety of potentially destabalising forces which can result in local delamination of the coating.

It is an object of this invention to provide plastic strain hardened sheet material and a method of forming such material whereby the sheet material will have improved tensile strength and the disadvantages of the prior proposals are alleviated.

According to the present invention there is provided ductile sheet material at least one region of which is plastic strain hardened to comprise an array of depressions and projections disposed longitudinally and laterally over both surfaces of the material with a depression in each surface having a corresponding projection on the other surface, the projections and depressions being disposed in their array with each depression in each surface interconnecting with the or each adjacent projection on the respective surface to provide a substantially sinusoidal profile to part of the respective surface presented by said interconnecting depression and adjacent projection whereby the material in said region is of sinusoidal shape in section through each depression and projection adjacent thereto in each surface.

Further according to the present invention there is provided a method of plastic strain hardening at least one region of ductile sheet material which comprises subjecting said region to male formers applied simultaneously to each surface of the material to locally stretch the material and form an array of depressions and projections disposed longitudinally and laterally over both surfaces of the material with a depression in each surface having a corresponding projection on the other surface, the projections and depressions being disposed in their array with each depression in each surface interconnecting with the or each adjacent projection on the respective surface to provide a substantially sinusoidal profile to part of the respective surface presented by said interconnecting depression and adjacent projection whereby the material in said region is of sinusoidal shape in section through each depression and projection adjacent thereto in each surface.

By the present invention it is preferred that the projections and depressions, when viewed from any point within the said region of the sheet, appear to radiate mainly continuously through 360° so that in excess of 75% and preferably not less than 95% of the original surface area has been plastic strain hardened. It is also preferred that any longitudinal or transverse cross-section of the material in said region appears typically as a sinusoidal shape.

The sheet material will preferably have an array of part spherical projections and corresponding depressions formed in each of its surfaces. Alternatively the sheet material may have an array of ellipsoidal projections and corresponding depressions formed in each of its surfaces. With this in mind the male formers will usually present either a part spherical or part ellipsoidal profile. With each of the above profiles the projections and depressions are arranged to merge one with another to produce a generally sinusoidal material flow between all interconnecting projections and depressions.

The area of sheet material subjected to plastic strain hardening is directly proportional to the number and diameter of the part spherical or ellipsoidal projections and depressions therefor the smaller the diameter the greater the area processed. However, larger diameters will allow higher projections and deeper impressions to be made, and the resultant sinusoidal curve produces higher levels of torsional strength in the sheet material.

A preferred embodiment of the sheet material is one which has the spacing and height dimensions of the projections comensurate with the conversion of the sheet into a coldformed section of predetermined design, and which includes multiple-intermediate stiffeners in flat compression elements of the section so that sub-elements of the section have a width to a thickness ratio which is less than 30, and in so doing allows all stiffeners to be considered as effective in accordance with British Standard 5950 Part 5 1987 (Section 4.7.3). It is recognised that to reproduce the preferred embodiment for each cold formed section design it will be necessary to compensate for differences in section geometry, element width, material thickness and the materials yield strength, and the invention permits an infinite variety of spacing and height/size dimensions related to the projections to be provided. Because all sizes of projections provide the required sinusoidal surface profile most surface treatments applied to the sheet prior to its deformation in plastics strain hardening are unlikely to be impaired (for example decorative paint finishes which have an elastic capability such as compositions sold under the Trade Marks Pvf2, Organosol and Plastisol).

Still further according to the present invention there is provided a method of plastic strain hardening at least one region of ductile sheet material which comprises subjecting said region to first male formers applied simultaneously to each surface of the material to locally stretch the material and form an array of depressions and projections disposed longitudinally and laterally over both surfaces of the material with a depression in each surface having a corresponding projection on the other whereby the material in which the projections are formed is subjected to plastic strain hardening, and subjecting said material in which the projections are formed to second, relatively larger, male formers applied simultaneously to each surface of the material to locally stretch the material further and form an array of relatively larger depressions and projections disposed longitudinally and laterally over both surfaces of the material with a relatively larger depression in each surface having a corresponding relatively larger projection on the other whereby the material in which the relatively larger projections are formed is subjected to further plastic strain hardening. With this aspect of the invention the array of depressions formed by the first or second male formers and the corresponding projections may be of any profile, for example, trapezoidal, ellipsoidal or part spherical, it being realised that by forming the relatively larger depressions over the relatively smaller depressions, the material in which the relatively larger depressions are formed is subjected to two stages of stretching and consequently two stages of work hardening to increase hardness and tensile strength of the material. Preferably the first and second male formers are arranged, so that the relatively larger depressions and corresponding projections and the relatively smaller depressions and corresponding projections (which may be present on the material and, to some extent, may be apparent in the relatively larger depressions) provide the sinusoidal characteristics to the surfaces of the material and to the section of the material as previously discussed. A typical embodiment is a sheet which has a first size of projections which have a diameter and height dimensions less than 5mm and which either cover the whole surface or are arranged in longitudinally extending bands or regions so that they are discontinuous laterally over the width of the sheet. A second size of projections having diameter and height dimensions in excess of 5mm may either be included with the first projections so that they merge with them, or applied as imprints so that the surface of the larger projections is itself imprinted with the first smaller projections. Two advantages of this embodiment are that the first array of smaller projections, plastic strain harden all predetermined areas of the sheet material, whilst the second array of larger projections increase the overall thickness of the sheet and perform as additional multiple-intermediate stiffness as previously described.

In the preferred method of the present invention two sets of opposing male formers are used to locally stretch the sheet material into interconnecting spheroidal protrusions transversley and longitudinally, and by doing so cause the sheet material to adopt a generally dimpled profile on each surface of sinusoidal cross section form where a section is taken through at least two adjacent depressions and projections.

The male formers, preferably spheroidal, used in stretching the sheet can be located in opposed flat surfaces of press tools or the surfaces of two opposed compression rolls suitable for inclusion in a cold rollforming machine. In both cases the formers rise above the surfaces and are arranged in rows which extend transversley and longitudinally on both opposed flat surfaces of the press tool, or in rows which both circumscribe and extend from end to end of each opposed compression roll. Preferably all of the male formers included on the top part of each tool set are spaced apart, and alternate rows are off-set. The formers in the bottom part of the tool sets are also preferably arranged so that when, in the case of the press tools, both parts are moved towards each other, and in the case of the compression rools, both are rotated, they enter the spaces which exist between formers included in the top parts of the tool sets. With such an arrangement of spheroidal or ellipsoidal formers, the sheet material is urged into its generally sinusoidal format as described, and they do so by applying a tensile force which instigates controlled ductile extension at the point of yield. This aspect of the invention also recognises that to reproduce the preferred sheet material embodiment having the sinusoidal characteristics previously described, it is necessary to compensate for the various issues which influence its format. As a consequence the invention provides various methods whereby the spacing and height dimensions of the spheroidal or ellipsoidal formers peculiar to a specific sheet material embodiment, can be accommodated. For example a first embodiment is when all spheroidal formers in a set or each set have identical diameters and heights, and they are closely spaced to satisfy the effective requirements of stiffeners as previously described for a preferred sheet embodiment. A second embodiment is when spheroidal formers in a set or each set are of different diameters but all with the same height.

A third embodiment is when there is more than one pair of male formers each of which pair forms a tool and such tools are used successively; in this case the additional tool or tools can incorporate formers which have larger diameter and height dimensions than those included in the tool which immediately precedes it. When all tool sets are preferably but not necessarily located in line, sheet material can be continuously processed to be formed with an array of different size projections.

A preferred arrangement has a diametrically opposed pair of cylindrical compression rolls which include spheroidal formers that have diameter and height dimensions capable of stretch forming, in sheet material of known thickness and tensile strength, an array of inter-connecting spheroidal projections and depressions in both surfaces so that the width to thickness ratio of sub-elements (as defined in British Standard 5950 Part 5 1987 - Section 4.7.3) of a particular cold rolled section into which the sheet material is to be rollformed, does not exceed 30.

Both cylindrical compression rolls may be included in a coldforming production line and connected one with the other and to the driving mechanism of the machine so that their rotation is synchronised one with the other and with the section forming roll tools so as to allow uninterrupted production of the required section.

The present invention also provides for cold formed sections and profiled sheets formed by bending of ductile metal sheet as previously specified as being in accordance with the present invention. The invention also provides for a tool by which ductile metal sheet as previously specified as being in accordance with the present invention can be produced.

Typical embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a fragmentary cross section view in diagrammatic form, of sheet material which has an array of spheroidal projections and depressions on both sides of the sheet similarly offset from the original plane of the sheet. All projections are identical and have diameter dimensions greater than height dimensions.

Figure 2 shows a fragmentary cross section view in diagrammatic form of sheet material which has on each surface an arry of spheroidal projections and depressions with similar dimensions to those in Figure 1 but formed symmetrical about the original plane of the sheet.

Figure 3 is a similar view to that shown in Figure 1 and illustrates the projections formed in the sheet material to have diameter and height dimensions which are equal.

Figure 4 shows a fragmentary plan view of sheet material which includes spheroidal projections that have identical diameters and are arrayed longitudinally and laterally in rows so that the projections and depressions cover the whole of both surfaces.

Figure 5 shows a fragmentary plan view of sheet material which includes spheroidal projections and corresponding depressions that have two different diameters and in which the larger projections are imprinted over smaller projections.

Figure 6 shows a fragmentary view in wire diagram format, of a sheet material which has been subjected to a plastic strain hardening method in accordance with the present invention and depicts the plastic flow of the parent ductile sheet and its completed new shape to present sinusoidal profile characteristics.

Figure 7 shows a variation of the sheet depicted in Figure 5 in which large diameter spheroidal projections and depressions interconnect forming three rows which are separated by four rows of smaller diameter spheroidal projections and depressions.

Figure 8 shows a sheet similar in format to that shown in Figure 7 but in this instance the centre row of larger projections/depressions are omitted to leave the sheet material in its original state along its longitudinal extent so that two longitudinally extending regions of depressions and projections are provided.

Figure 9 illustrates a fragmentary plan view of sheet material which has two regions of spheroidal projections and depressions separated by an area which runs longitudinally and is free of projections and depressions.

Figure 10 is an end elevation of an angle section which may be formed with sheet material of the present invention.

Figure 11 shows a fragmentary plan view of sheet material which has three longitudinally or laterally extending regions of spheroid projections and depressions which are separated by two regions that are free of any projections/depressions.

Figure 12 is an end elevation of a simple Zed section which may be formed with sheet material of the present invention.

Figure 13 illustrates a fragmentary front elevation view of an opposing pair of cylindrical compression rolls of a tool having inter-relating spheroid projections on both sides of sheet material. The illustration depicts the sheet width or lateral extent.

Figure 14 shows a fragmentary end elevation view of the pair of compression rolls shown in Figure 13 with the sheet material passing between them in a longitudinal direction.

Figure 15 shows two opposing sets of spheroidal male formers in a tool stretching sheet material into spheroid projections and corresponding depressions. The illustration is a front elevation cross section.

Referring firstly to Figures 1 and 2 it can be seen that it is possible to have part spherical projections 7 and depressions 3 of similar dimensions on both sides of ductile metal sheet material 1. However, the overall thickness of the sheets, that is the distance between the parallel planes of the crests of the projections on each surface (i.e. the distance between the datum plane or line 1 and crest 2 in Figure 1) is double that for the sheet shown in Figure 2 as compared with that shown for the sheet in Figure 1, consequently the tensile strength of the sheet in Figure 2 is higher than that for the sheet in Figure 1, and both sheets have a higher tensile strength than that of the original sheet from which they were both formed. Because the spheroid projections 3 are dimensionally identical, both sheets can be produced by the same tools as will be explained later.

Figure 3 illustrates that it is possible to obtain a sheet which has a similar overall thickness to that shown in Figure 2, even though the spheroid projections and depressions are displaced to one side of the sheet. This is achieved when the diameter and height dimensions are equal.

Figures 1, 2 and 3 illustrate that the preferred spheroid projections 7 and corresponding depressions 3 reproduce in a cross section view of any group of projections and depressions taken at any point on the sheet material, a generally sinusoidal configuration.

From Figure 4 it will be appreciated that if the diameter of the spheroid projections 7 is small, then the surface area 6 of material interspersed between projections 7 and depressions 3 on each surface which has limited experience of plastic strain hardening, will also be small (or smaller than that between relatively larger diameter projections.

Figure 5 illustrates the effect of combining at least two sizes of projections and corresponding depressions. In this instance the sheet material 1 has first been subjected to a plastic strain hardening process brought about by forming small spheroid projections 7 on each surface of the sheet with corresponding depressions 3 on the other surface of the sheet. The surface area 6 between projections and depressions on each surface may therefore be small. However, by imprinting larger interconnecting spheroid projections 5 and corresponding depressions 5A over the smaller projections 7 from each surface of the sheet the effect is to generally achieve total cover of the sheet material with spheroid projections and depressions radiating through 360° from any point on a surface. This arrangement combines the benefits of plastic strain hardening with those of multiple stiffening forms, and the result is that the tensile strength of the sheet material has been maximised, bearing in mind of course the composition and performance characteristics of the parent sheet material.

Figure 6 illustrates how the parent sheet material undergoes a plastic flow process which transforms the texture of its surfaces and as a consequence its cross section form. Longitudinal flow lines 8 and transverse flow lines 9 have adopted a generally sinusoidal form which contributes to increase the tensile strength even when the spheroid forms which produced the plastic flow have a height dimension which is little more than twice the parent sheets original gauge.

Figure 7 illustrates a variation of the larger and smaller spheroid projections and corresponding depressions shown in Figure 5. The possible permutations are almost limitless so that all ductile sheet material classified as suitable for cold forming can be plastic strain hardened by the invention, and because each projection is a spheroid there are no parts of the projection which have been subjected to uneven compression forces. As a consequence both surfaces of the sheet have been evently stretched so that surface treatments which were applied to the parent sheet material should remain unaffected and continue to perform their intended function. The arrangement of the projections as shown in Figure 7 indicates that larger diameter projections 5 have been included in three rows 10, 11 and 12 and these will increase the overall thickness of the sheet material by any predetermined factor necessary when the projections are to act as stiffeners in a flat compression element of a cold formed section produced from the sheet. It will be appreciated that the arrangement shown in Figure 7 can be produced in different scales which is a particularly useful feature when sheet materials of various specifications are to be plastic strain hardened.

Figure 8 shows variation of the projections arrangement shown in Figure 7. The main difference is that row 11 in Figure 7 has been omitted so that there is a longitudinal region of sheet material 13 extending throughout its length which remains in its original state and separates longitudinal regions of the sheet on which the projections and depressions are formed. This type of variation is useful especially when sheet material is to be formed into cold roll formed sections.

Figure 9 illustrates a typical plastic strain hardened sheet of predetermined width as designated by lines 14 and 15 and which contains a region 13 of material that does not contain any projections. This arrangement is typical of sheet material which is to be cold formed in to an angle section and where the bend is formed along the region 13 to be free of projections 7.

Figure 10 shows the angle section produced from the sheet material shown in Figure 9. It shows that legs 16 and 17 contain regions 18 having required spheroid projections and corresponding depressions and bend area 19 clear of projections so that the sheet can be more easily formed into the angle section. Although this may be a desirable feature on occcasions it is not exclusively so, and sections can be cold formed from sheet material which does not have any region clear of projections/depressions.

Figure 11 shows sheet material with three regions 20, 21 and 22 of spheroid projections/depressions interspersed by two regions 13 of original material. As with Figure 10 the sheet is to be formed in to a cold formed section, but in this instance the section is to contain two bends.

Figure 12 shows one type of cold formed section which could be produced from the sheet material shown in Figure 11. The particular section illustrated is a simple Zed section which has its web 23 and flanges 24 and 25 plastic strain hardened by the inclusion of spheroid projections and depressions as shown as regions 20, 21 and 22 in Figure 11. Two bends 19, formed in region 13 of Figure 11 are free of projections and depressions in this embodiment. A simple channel section (not shown) could also be cold formed out of the sheet material shown in Figure 11.

Although plastic strain hardened sheet material of the present invention in its processed planar form will have many commercial uses, it is likely that the sheet material will mainly be utilised in the manufacture of cold formed sections and profiled sheets (not shown). Therefore, it is recognised that to produce preferred embodiments of each section or profiles it is desirable that the production method must be more flexible than known methods such as those used to produce the trapezoidal shaped formations referred to earlier. Differences in section geometry; flat compression elements, and sub-element widths in structural sections; material thickness, yield strength, and surface coating; are all factors which must be taken into consideration, as are those issues concerned with production efficiency and productivity. This invention is also concerned with production tools which can be included in a cold roll forming production line of normal configuration, so that the flat ductile sheet metal material can be continuously processed in to its final plastic strain hardened section or profiled sheet form.

Figure 13 illustrates an arrangement of spheroidal male formers 26 of a production tool and which are disposed in two opposing sets one on each of top and bottom cylindrical compression rollers 27 and 28 wherein a first row of formers 30 in the bottom roller have engaged the sheet material 31 and formed or stretched it in to a generally sinusoidal shape when viewed as a cross-section elevation. A second row of spheroid formers 32 in the top roller and 33 in the bottom roller are spaced from the first rows 29 and 30 so that one point on their diameters will be spaced at a distance approximately the same as the thickness of the sheet material which is being formed. An example of the spacing is shown at 34. It is shown by transverse rows 29 and 30 that the space 35 between each former in a row is equivalent to the diameter of a former plus approximately two thicknesses of the sheet material. It can also be seen that the formers in row 32 are offset to those in row 33 so that when both top roller 27 and bottom roller 28 are rotated clockwise 36 and anti-clockwise 37 (as shown by the arrows in Figure 14) formers in row 32 and 33 will merge into the positions of formers shown in row 29 and 30. Similarly the formers 26 in row 38 of the top roller 27 and row 39 in the bottom roller 28 are off set one with the other so that they will also merge as stated when top roller 27 and bottom roller 28 are rotated in the manner described. This positioning of formers 26 is extended around the circumferences of both rollers 27 and 28 and therefore the metal sheet material 31 will contain projections 7 and corresponding depression 3 which merge one with the other longitudinally and transversely to produce the sinusoidal plastic flow in the sheet material as shown in Figure 6.

Figure 14 shows the top and bottom cylindrical compression rollers 27 and 28 in end elevation and shows how the spheroid formers 26 form the spheroid projections 7 in the ductile sheet material 31 in the longitudinal direction 8 shown in Figure 6. To allow the sheet material 31 to stretch form to its optimum spheroid height, a space 40 can be maintained by adjusting the distance that tools 27 and 28 are set apart. This adjustment feature can be used to increase the versatility of a pair of rollers in a tool. By increasing or decreasing the compression force exerted by the rollers to produce projections and depressions of different diameters and heights disposed over both sides of the sheet material. The fact that the formers 26 are spheroids ensures that they are capable of withstanding considerable compressive forces without suffering damage, therefore they are well suited to forming the spheroid projections in high tensile grades and thicker gauges of sheet material, than is possible with other shaped formers. In an alternative embodiment, not shown, the spheroid formers are replaced by ellipsoidal male formers to provide similar advantages and characteristics of metal stretching to those described for the spheroid formers.

A preferred arrangement of the tools is when the cylindrical bodies of the rollers 27 and 28 are produced as tool holders so that spheroid or ellipsoidal male formers can be inserted into holes (not shown) which may be threaded. The formers in this situation could be in the shape of a one piece component which has a spheroid or ellipsoidal head and threaded shank (not shown). One advantage of this roller configuration is the ease with which it is possible to change the formers, and a second advantage is that it is possible to insert between the head of the former and the surface of the cylindrical body of a roller 27 or 28 one or more shims which increase the height of the formers and by so doing allow larger projections to be made in ductile sheet material. A third advantage is that the formers can be made of high grade tool steel and case hardened if required, whereas the cylindrical bodies of the rollers can be produced to less exacting standards.

Figure 15 illustrates how metal sheet material 31 is stretch formed by opposing sets of spheroid formers (of which three formers 26 are shown in each set) so that the sheet is thinner at each apex 41 of each spheroid projection 7 than it is at the point 42 where projections 7 merge one with another.

A second production tool with a pair of cylindrical compression rollers (not shown) can be provided and through which the sheet material having relatively small projections and corresponding depressions already formed can pass to stretch form relatively larger interconnecting spheroid projections 5 as shown in Figures 5 and 7. The tools as above described permit almost limitless permutations of sizes and dispositions of spheroid projections and depressions to be formed in the sheet material.

CLAIMS

1. Ductile sheet material at least one region of which is plastic strain hardened to comprise an array of depressions and projections disposed longitudinally and laterally over both surfaces of the material with a depression in each surface having a corresponding projection on the other surface, the projections and depressions being disposed in their array with each depression in each surface interconnecting with the or each adjacent projection on the respective surface to provide a substantially sinuous profile to part of the respective surface presented by said interconnecting depression and adjacent projection whereby the material in said region is of sinuous shape in section through each depression and projection adjacent thereto in each surface.

2. Material according to Claim 1 wherein the projections and depressions, when viewed from any point within the said region of the sheet, appear to radiate mainly continuously through 360^0 so that in excess of 75% of the original surface area of the region is plastic strain hardened and any longitudinal or transverse cross-section view of the material in said region appears typically as a sinuous shape.

3. Material according to Claim 1 and Claim 2 wherein the array of projections and corresponding depressions formed in each of its surfaces are either part spherical or ellipsoidal in shape

4. Material according to Claim 3 wherein parent material separating oblique pairs of part spherical or ellipsoidal projections and depressions adopts a generally elongate sinuous shape so that not less than 95% of the surface area within the said region is plastic strain hardened.

5. Material as claimed in Claim 3 and Claim 4 wherein there is an array comprised of at least two different size interconnecting projections and depressions disposed longitudinally or laterally or longitudinally and laterally within the said region.

6. Material according to Claim 3, Claim 4, and Claim 5, wherein there is superimposed upon a first array of any shape, size, and combination thereof, projections and depressions, a second array of relatively larger size interconnecting part spherical or ellipsoidal projections and depressions disposed longitudinally and laterally over both surfaces of the material so that the overall thickness of the material as measured from the crest of projections on one side to the crest of projections on the other side of the material is not less than twice that of the thickness of the parent material.

7. Material according to any preceding claim wherein its end elevation view is generally representative of either a coldformed section design or coldformed profile sheet design which is plastic strain hardened in any one or combination thereof of its elements.

8. Material as claimed in Claim 7 wherein interconnecting part spherical or ellipsoidal projections and depressions have height dimensions which achieve a overall thickness dimension compatible with a width to thickness ratio of less than 30 in sub-elements of flat compression elements of said coldformed section designs and coldformed profile sheet designs.

9. Material according to any preceding claim wherein the parent ductile sheet material includes an elastic pretreated surface finish so that all versions of the plastic strain hardened material in this format are prefinished.

10. A method of plastic strain hardening at least one region of ductile sheet materials, including those with pretreated surface finishes ,which comprises subjecting said region to a tensile force applied simultaneously by male spheroidal or ellipsoidal formers to each surface of the material to achieve controlled ductile extension at the point of yield and by so doing produce an array of depressions and projections disposed longitudinally or laterally or longitudinally and laterally in both surfaces of the ductile material so that the material in the said region is of sinuous shape in section through each depression and projection adjacent thereto in each surface.

11. A method according to Claim 10 wherein male formers are located in opposed flat surfaces of a press tool or the opposed surfaces of two interactive compression rolls whereby the formers stand proud of the surfaces and are arranged in rows which extend transversely and longitudinally on both opposed press tool surfaces and in rows which circumscribe and extend from end to end of each opposed compression roll.

12. A method according to Claim 11 wherein formers situated in one part of a tool set are set apart within each row and formers in alternate rows in the same tool part are offset so that no former in the part is in contact with any other former in the same part and a similar format applies to formers located in the other half of the tool set except that in this case the formers are positioned so that they locate between formers in the first tool part when both parts are engaged.

13. A method according to Claim 11 and Claim 12 wherein male spheroidal or ellipsoidal formers of at least two different sizes are included in a tool set.

14. A method according to Claim 12 and Claim 13 wherein there is provided at least two tool sets with formers in the second and any subsequent set being larger than those in the set which proceeds it so that when used sequentially the smallest projections and depressions are over layed by larger projections and depressions.

15. A method according to Claim 12, Claim 13, and Claim 14 wherein a tool set comprising two opposed cylindrical compression rolls containing spheroidal formers are mounted in a tool holder so that one or both compression rolls can be positionally adjusted to either increase or decrease the compression force they exert upon material passing between them, thus increasing or decreasing the height and diameter of projections, and depth and diameter of depressions on both sides of the material.

16. A method according to any one of claims 10 to 15 wherein tool sets comprise a main body and detachable formers so that the main body performs as a tool holder capable of accommodating a variety of different size spheroidal or ellipsoidal formers.

17. A method according to any one of claims 10 to 16 wherein at least one cylindrical compression roll set is included in a coldformed section or coldformed profile sheet rollforming production

line so that its work station position within the line is the most suitable for plastic strain hardening sub-elements of the flat compression elements of the said coldformed section or profile sheet.

18. Ductile sheet material substantially as herein described with reference to and as illustrated in Figures 1 to 12 of the accompanying drawings.

19. A method substantially as herein described with reference to Figure 13, Figure 14, and Figure 15 of the accompanying drawings.

Patents Act 1977 **Examiner's report to the Comptroller under Section 17** **(The Search report)** -25-	Application number GB 9313734.7
Relevant Technical Fields (i) UK Cl (Ed.M) B3E, B3Q (ii) Int Cl (Ed.5) B21D 22/00, B21H 1/00	Search Examiner A R MARTIN Date of completion of Search 20 SEPTEMBER 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI, CLAIMS	Documents considered relevant following a search in respect of Claims :- ALL CLAIMS

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Category	Identity of document and relevant passages		Relevant to claim(s)
X	EP 0144870	(MUNZ) see Figures 1 and 3	Claims 1 and 10 at least
X	EP 0020829	(TATE) see Figure 3	Claims 1 and 10 at least
X	US 4025996	(SAVEKER) see Figure 1	Claims 1 and 10 at least
X	US 3992835	(SAVEKER) see Figure 1	Claims 1 and 10 at least

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