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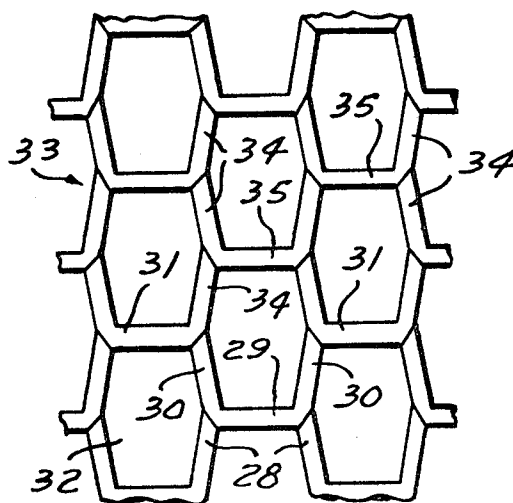
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[54] **PRESTRETCHED EXPANDED METAL AND METHOD OF MAKING IT**
13 Claims, 22 Drawing Figs.

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 [51] Int. Cl. **H01m35/04,**
 B21c 37/00
 [50] Field of Search 136/37, 36,
 38, 20, 28, 30; 29/6.1, 6.2, 193.5; 72/392; 52/635,
 670, 672

ABSTRACT: After production of expanded metal in substantially the usual way, sheet is stretched longitudinally until the strands in at least some of the rows become substantially longitudinally aligned. Punch may be shifted a distance equal to about one-third the tooth width to produce asymmetric diamond-shaped openings prior to stretching. Sheet may be bent longitudinally upon itself along a row of aligned strands to yield a smooth edge. Electrode may be formed by applying a chemically active powder to sheet.



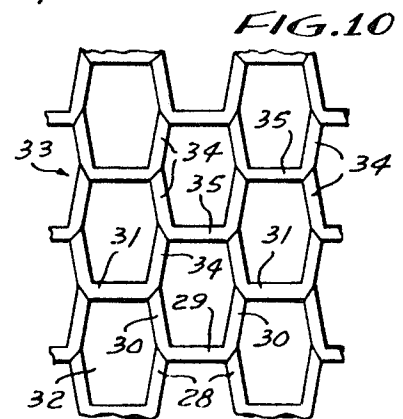
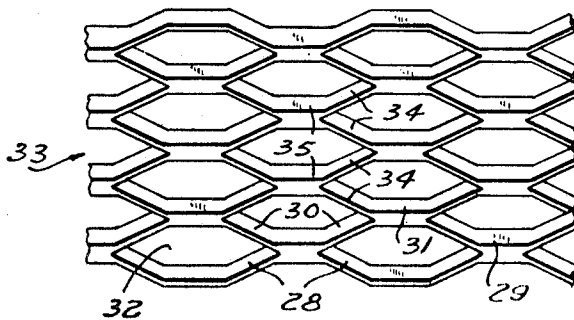
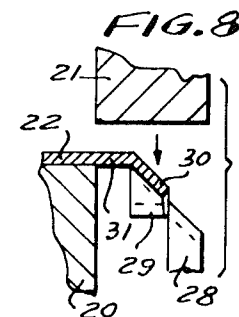
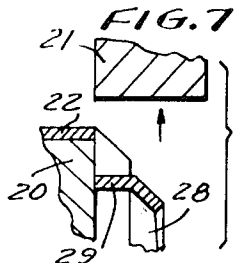
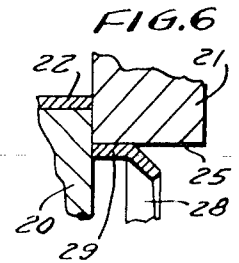
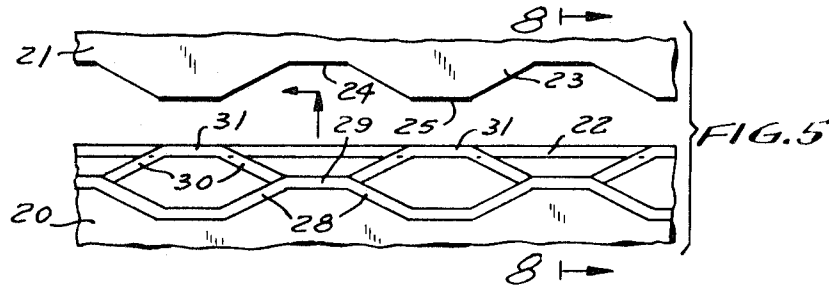
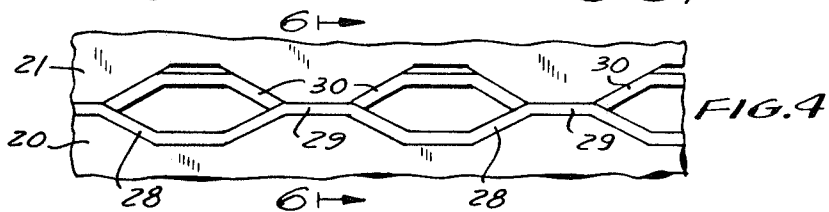
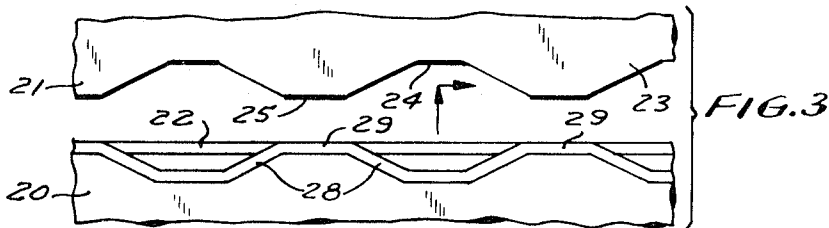
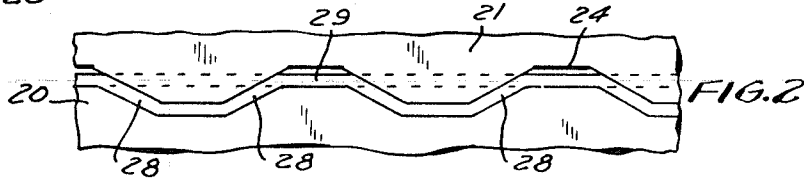
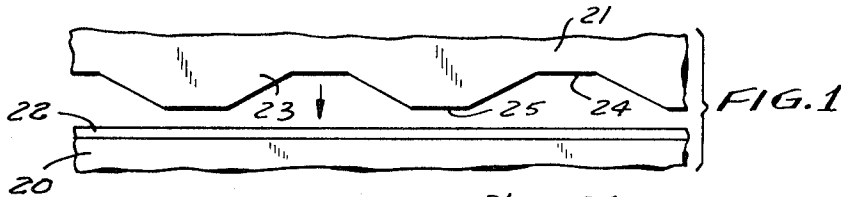


FIG. 9

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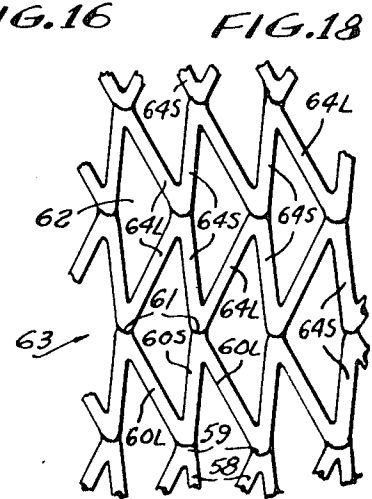
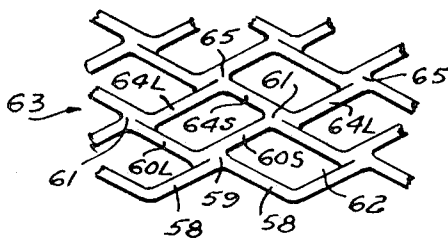
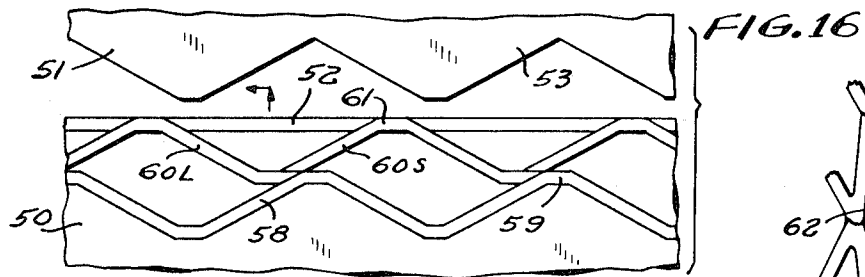
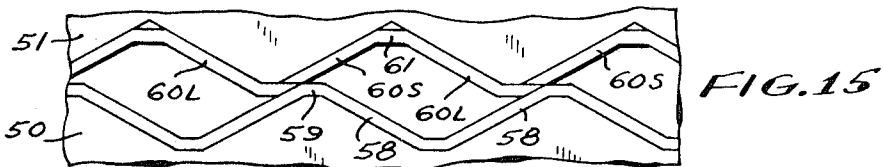
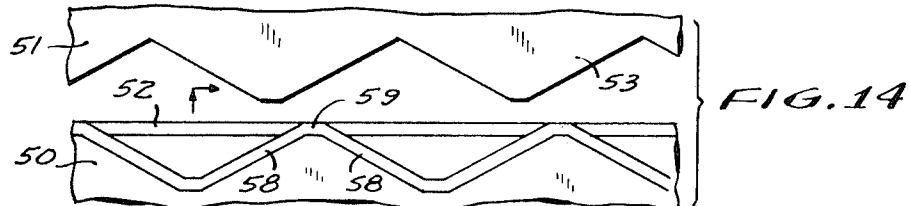
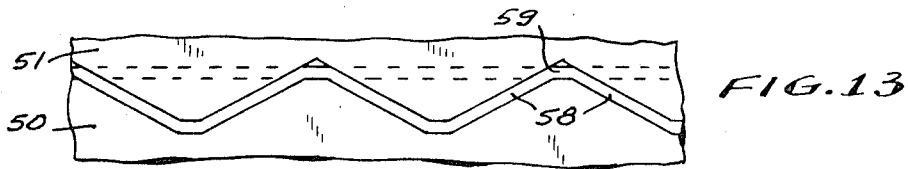
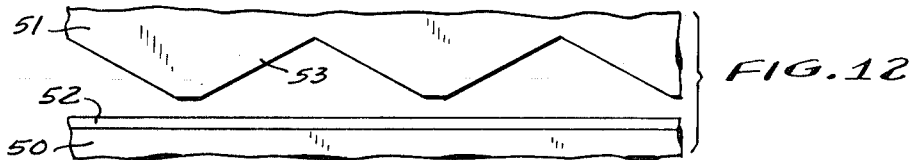
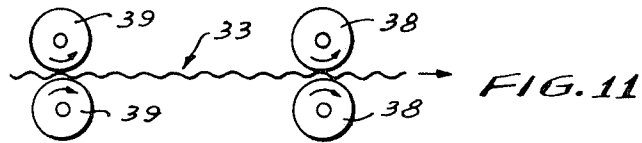


FIG. 17

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FIG. 19

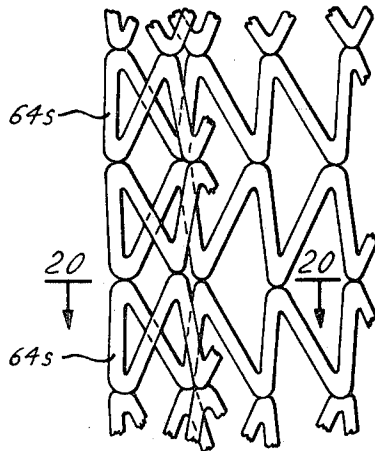


FIG. 20



FIG. 21

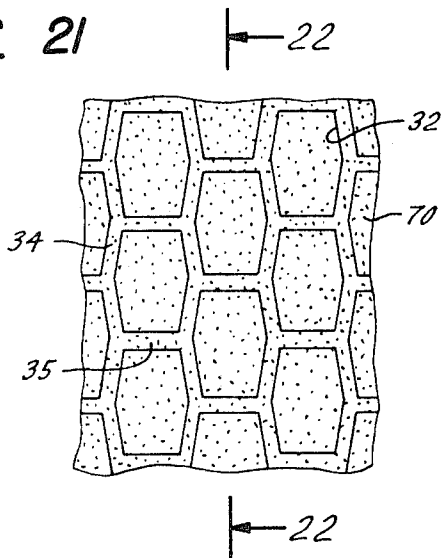
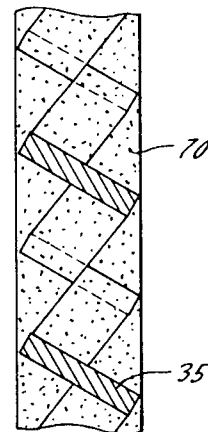


FIG. 22



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PRESTRETCHED EXPANDED METAL AND METHOD OF MAKING IT

This invention relates to expanded metal, and more particularly to expanded metal having reduced longitudinal stretchability, the term "longitudinal" referring to the direction in which the metal sheet is advanced during the expanding procedure.

Expanded metal is in itself well known. It is a sheet or web of metal having longitudinal rows of diamond- or hexagonal-shaped openings, the openings in adjacent rows being separated by expanded strands, and the adjacent openings in each row being separated by connecting bridges between the strands. Each strand extends between two connecting bridges at an acute angle to the longitudinal direction of the web.

When the expanded metal web is intended for certain end uses, the expanded strands are made of very fine gauge (e.g., 0.005-inch material thickness, 0.010-inch strand width) and the expanded metal web is run longitudinally through additional equipment to further process it. For example, in the manufacture of electrodes for electrochemical cells, expanded metal is processed so as to apply a chemically active powder to it. During this further processing, the web is subjected to longitudinal pulling and as a result the strands have a tendency to rotate about their ends in a direction which brings them closer to alignment with the direction of the pulling force, i.e., the longitudinal direction. This reaction to longitudinal pulling causes certain problems. Rotation of the strands toward the longitudinal direction causes a corresponding narrowing of the web. However, since the amount that different strands rotate is not uniform, due in part to the fact that different parts of the web may be subjected to different pulling forces, the web becomes distorted since it narrows in a nonuniform and unpredictable manner. Furthermore, the sizes of the openings in the web become nonuniform.

It is an object of the present invention to overcome these and other problems by providing expanded metal which has greatly reduced longitudinal stretchability, regardless of how fine the gauge of its strands.

It is another object of the invention to provide expanded metal having an increased proportion of the sheet area occupied by openings, as compared to an otherwise identical sheet expanded by the same punch driven to the same depth of penetration.

It is a further object of the invention to provide a method for producing such expanded metal.

To achieve these objectives, the invention contemplates making expanded metal substantially in the usual way on conventional metal-expanding equipment, and thereafter stretching it longitudinally, in a controlled manner with uniformly applied force along its entire length, to bring all the strands in at least some of the rows into longitudinal alignment. This stretching is done prior to any further processing of the expanded metal web, so that no additional stretching takes place during such processing. An additional benefit of the stretching operation is that the connecting bridges between the strands in adjacent rows are rotated toward a position perpendicular to the plane of the sheet, thus increasing the overall thickness of the material. Consequently, the material-holding capability of the openings is increased.

If the punch moves through a distance equal to one-half the width of one tooth during each lateral reciprocation, openings in the shape of symmetrical diamonds or hexagons are formed in the sheet. On the other hand, if the punch moves a different distance during each lateral reciprocation, say one-third the tooth width, openings in the shape of asymmetrical diamonds are formed. In the former case, the prestretching procedure serves to align all the strands longitudinally, but in the latter case, because the strands in every other row are shorter, only they are aligned longitudinally.

A feature of the invention involves the fact that an expanded metal sheet stretched according to the present invention can readily be provided with a smooth longitudinal edge by simply bending the sheet upon itself along a longitudinal row of aligned strands.

Additional features and advantages of the invention will be apparent from the following description in which reference is made to the accompanying drawings.

In the drawings:

FIG. 1 is a fragmentary elevational view of a conventional shear plate and punch at the commencement of a sequence of operations resulting in formation of expanded metal;

FIGS. 2-5 are similar views of successive operations;

FIG. 6 is a cross-sectional view along line 6-6 of FIG. 4;

FIG. 7 is a view similar to FIG. 6 showing a subsequent step in the process;

FIG. 8 is a cross-sectional view along line 8-8 of FIG. 5;

FIG. 9 is a face view of a piece of the resultant conventional expanded metal;

FIG. 10 is a view similar to FIG. 9 after stretching of the sheet according to this invention;

FIG. 11 is a schematic elevational view of apparatus for stretching the web;

FIGS. 12-16 are views similar to FIGS. 1-5, showing an alternative embodiment of the invention;

FIG. 17 is a face view of a piece of the expanded metal resulting from the procedure of FIGS. 12-16;

FIG. 18 is a view similar to FIG. 17 after stretching of the sheet;

FIG. 19 is a face view of a piece of stretched expanded metal bent upon itself to produce a smooth edge;

FIG. 20 is a cross-sectional view along line 20-20 of FIG. 19;

FIG. 21 is a fragmentary face view of an electrode incorporating a piece of stretched expanded metal according to this invention; and

FIG. 22 is a cross-sectional view along line 22-22 of FIG. 21.

The size of expanded metal shown in the drawings has been greatly exaggerated for the sake of clarity of illustration. In fact, the present invention relates to products wherein a typical cross-sectional dimension of a strand is of the order of 0.008 inch.

Referring to FIGS. 1-8, a shear plate 20 and punch 21 are arranged in shearing relationship. A sheet of metal 22 to be treated is advanced intermittently (in the direction of the observer in FIGS. 1-5) to bring successive regions into an overhanging relation to the shear plate 20 and thus subject them to the shearing action of the punch 21. These advancements of the metal 22 occur during periods that the punch 21 is withdrawn from the shear plate (FIGS. 1, 3, and 5). During these periods there is also a relative lateral shift of the punch 21 and sheet 22. The punch 21 is serrated, i.e., it has teeth 23 separated by recesses or depressions 24. These can be shaped or contoured in various ways to produce correspondingly different effects. For example, in FIGS. 1-5, each tooth 23 is blunted so that it terminates in a relatively long tooth "flat" 25.

Assuming in FIG. 1 that the sheet 22 is in a position in which its advancing margin overhangs the edge of the shear plate 20 by the desired amount, the punch 21 is now caused to descend to its lowest position shown in FIG. 2. This shears and expands the strands 28, which nevertheless remain connected to the parent sheet in the regions 29 between the teeth 23 of the punch 21. The punch then withdraws and shifts laterally relative to sheet 22, as indicated by the arrows in FIG. 3. In the case of FIGS. 1-5, the amount of lateral shift equals one-half the width of one tooth 23, i.e., one-half the distance from the center of one depression 24 to the center of the next successive depression.

During the period of lateral shift, the sheet 22 advances again to bring the next successive region into shearing position. On the next descent of the punch 21 (FIG. 4), the teeth encounter the regions 29 thereby shearing and expanding the next row of strands 30. These are similarly retained in connected relation to the parent sheet in the regions 31 between the teeth 23 of the punch. Again, the punch 21 withdraws (FIG. 5) and shifts back to the position of FIG. 1 while the

sheet 22 advances again. This sequence of steps is repeated as often as desired. The resultant product 33 is shown in FIG. 9, there being successive staggered transverse rows of sheared and expanded strands linked together by connecting bridges. In FIG. 9, the two rows at the bottom are numbered to correspond to the procedural steps described in connection with FIGS. 1-8.

It will be seen in FIG. 9 that the openings 32 in the expanded metal sheet 33 have the shape of symmetrical hexagons, each opening being defined by four strands 28, 30, or 34 (hereinafter referred to collectively by the numeral 34), and two connecting bridges 29, 31, or 35 (hereinafter referred to collectively by the numeral 35). The relatively long connecting bridges result from the use of relatively long flats 25 on the teeth 23 of the punch, and limiting the depth of penetration of the punch to that shown in FIGS. 2 and 4. The symmetry of the hexagons is a result of shifting the punch laterally a distance equal to precisely one-half the width of a tooth 23. Each strand 34 extends at an acute angle to the longitudinal direction of the sheet 33 (the longitudinal direction being the direction in which the sheet advances as it moves between the punch 21 and shear plate 20, i.e., the vertical direction in FIG. 9) between connecting bridges 35 in two adjacent longitudinal and transverse rows. Due to the angled condition of the strands 34, when the web 33 is subjected to a longitudinal stretching force, each strand has a tendency to rotate about the points at which it is connected to its respective connecting bridges toward a position of alignment with the longitudinal direction of the web.

Therefore, according to this invention, fine gauge expanded metal which is to be further processed in such a way that it is subjected to longitudinal pulling forces is prestretched after its manufacture, as described above, and before it is further processed. Prestretching may be accomplished in a number of ways. For the purposes of the present invention, any stretching apparatus which applies a uniform longitudinal force to the expanded metal web along its entire length may be employed. Such an apparatus is shown schematically in FIG. 11, and includes two pairs of nip rollers 38 and 39 between which the expanded metal web 33 passes from left to right. The web is gripped by the rollers, and the front rollers 38 rotate faster than the rear rollers 39, whereby the web experiences stretching in the region between the rollers. To insure uniform stretching of the web, the pulling force on the web can be monitored continuously and variations in this force from a predetermined standard used to vary the speed of one of the pairs of rollers to compensate for the force variations. In the alternative, the front rollers may be driven through a magnetic clutch (not shown) adjusted to slip when the pulling force exceeds a predetermined standard.

The predetermined standard pulling force applied to the web 33 should be a force which is just sufficient to bend the metal, in the regions at which the strands 34 join the connecting bridges 35, beyond its elastic limit and to a degree sufficient to bring the strands 34 in each longitudinal row into substantially longitudinal alignment, as shown in FIG. 10. Several characteristics of the original expanded metal web of FIG. 9 have been altered by stretching it to the condition of FIG. 10. The length of the web has been increased and its width decreased. More important, the web of FIG. 10 is practically unstretchable in a longitudinal direction, and the openings 32 occupy a larger proportion of the face area of the web of FIG. 10 than in the case of the FIG. 9 web. Furthermore, the connecting bridges 35 are closer to being perpendicular to the plane of the sheet. Thus, the effective thickness of the sheet is increased. This effect, together with the increase in the proportion of openings, serves to increase the material holding capacity of the sheet. The significance of this will be seen below with reference to the electrode of FIGS. 21 and 22.

An alternative embodiment of the invention is illustrated in FIGS. 12-18. In general, the apparatus of FIGS. 12-16 is the same as that of FIGS. 1-5, with the exception that the teeth 53 of punch 51 are more pointed, i.e., the long tooth flat 25 has

been eliminated, or at least greatly minimized. However, the shear plate 50, and the sheet metal 52 which is acted upon, may be identical to the corresponding parts 20 and 22. One other distinction involves the fact that during the lateral shifting of the punch 51, the latter does not move through a distance equal to one-half the tooth width as does the punch 21, but instead through a distance other than a whole number multiple of one-half the tooth width. In the example illustrated, the shift distance equals one-third the tooth width.

When the punch 51 descends from the position of FIG. 12 to that of FIG. 13, strands 58 are sheared and expanded, but remain connected to the parent sheet in the regions 59 between the teeth 53. The punch then withdraws and shifts laterally, as indicated by the arrows in FIG. 14, during which period the sheet 52 advances. The next descent of the punch 51 (FIG. 15) produces the next transverse row of sheared and expanded strands 60L and 60S, connected to the parent sheet in the regions 61. These strands are not all of equal length, as is true of the strands 28, 30, and 34 of FIGS. 1-9. Instead, every other strand in the transverse row is relatively long, and is identified by the reference numeral 60L, and the alternate strands are relatively short, and identified by the reference numeral 60S. The punch again withdraws and shifts laterally, as indicated in FIG. 16, and the process is repeated.

The resultant product 63 is shown in FIG. 17, the openings 62 having the shape of asymmetric diamonds. The asymmetry results from the fact that the punch is shifted laterally a distance which is a fraction of one-half the width of a tooth 53. Each opening 62 is defined by two adjacent short strands, e.g., 60S and 64S, and two adjacent long strands, e.g., 60L and 64L (hereinafter all short strands will be referred to by the numeral 64S, and all long strands by the numeral 64L). Each long strand 64L is bent near one end, and the bent portion overlaps a portion of its adjacent long strand. However, the overlapped portions of the long strands are unconnected except at the connecting bridges 59, 61, and 65.

Since the strands are all arranged at an acute angle to the longitudinal direction of the expanded metal web 63 of FIG. 17, these strands also have a tendency to rotate about their points of connection to their respective connecting bridges when a longitudinal pulling force is applied to the web. Therefore, it is desirable to subject the web of FIG. 17 to the action OF the apparatus of FIG. 11 so as to produce the product shown in FIG. 18. With the web in the stretched condition of FIG. 18, the short strands 64S of each longitudinal row are in substantially longitudinal alignment, the short strands occupying every other longitudinal row. However, the long strands 64L, occupying the alternate rows, are arranged in a sawtooth pattern. Due to the substantial alignment of the strands 64S, the web 63 of FIG. 18 is practically unstretchable in a longitudinal direction. In addition, the proportion of the total area of the sheet occupied by the openings 62 in FIG. 18 is greater than the proportion occupied by the openings in FIG. 17.

It should be pointed out that the term "stretching" as used above and in the following claims is intended to mean lengthening of the sheet or web of expanded metal as a whole by virtue of rotation of the strands, and does not contemplate lengthening of the individual strands.

A benefit of prestretched expanded metal as described above, and illustrated in FIGS. 10 and 18 resides in its ability to be readily provided with a smooth longitudinal edge. One of the problems presented by conventional expanded metal is that its longitudinal edges are ragged. It has been found that if prestretched expanded metal according to this invention is bent upon itself, as shown in FIGS. 19 and 20, along a longitudinal line, it inherently tends to bend along a longitudinally aligned row of strands 64S. Since the strands of this row, now located along the longitudinal edge of the sheet, are all interconnected and present no sharp cut edges, the bent longitudinal edge of the sheet is smooth.

As mentioned above, one use of prestretched expanded metal as described above is in the formation of electrodes for electrochemical cells, such as of nickel-cadmium, silver-zinc,

or metal-air batteries. A portion of such an electrode is shown in FIGS. 21 and 22. It will be noted that the electrode has been formed by filling the openings 32 of the sheet with a suitable chemically active powder 70. The more common powdered materials used for this purpose are zinc, silver, nickel, zinc oxide, and silver oxide. The powder may be applied to the expanded metal in a number of ways. For example, the prestretched expanded metal sheet may be pulled through a slurry containing the powder, the excess slurry doctored off both faces of the sheet, and the sheet dried. The finished electrode may be used in a conventional manner in an electrochemical cell.

The invention has been shown and described in preferred form only, and by way of example, and many variations may be made in the invention which will still be comprised within its spirit. It is understood, therefore, that the invention is not limited to any specific form or embodiment except insofar as such limitations are included in the appended claims.

What is claimed is:

1. A sheet of expanded metal having a longitudinal direction defining a longitudinal axis and rows of openings in said longitudinal direction, said openings being delimited by strands defining the lateral boundaries of the openings and connecting bridges between the strands defining the forward and rearward boundaries of the openings said connecting bridges being substantially perpendicular to, the longitudinal axes of all the strands along at least one side of each row of openings being substantially aligned and substantially parallel to all the other aligned rows of strands, the longitudinal axes of said aligned strands extending along the longitudinal direction of the sheet.

2. A sheet of expanded metal as defined in claim 1 wherein the longitudinal axes of all the strands along each side of each row of openings are substantially aligned and substantially parallel to all the other aligned rows of strands.

3. A sheet of expanded metal as defined in claim 2 wherein all said substantially aligned strands are substantially perpendicular to the connecting bridges to which they are connected.

4. A sheet of expanded metal as defined in claim 1 wherein the longitudinal axes of the strands in only every other row are substantially aligned, the strands in the alternate rows being arranged in a sawtooth pattern.

5. A sheet of expanded metal as defined in claim 4 wherein said connecting bridges are arranged in longitudinally spaced-apart transverse rows, each strand of the sawtooth pattern extending between a connecting bridge located at the intersection of one of said transverse rows and one of said aligned rows of strands and another connecting bridge located at the intersection of the next successive transverse row and the next successive aligned row of strands.

6. A sheet of expanded metal as defined in claim 5 wherein each two successive strands of the sawtooth pattern are arranged at an obtuse angle to each other.

7. A sheet of expanded metal as defined in claim 1, said

sheet being bent upon itself along a longitudinal row of aligned strands, said row of aligned strands thereby forming a smooth longitudinal edge of the sheet.

8. A method of making a sheet of expanded metal comprising the steps of advancing sheet metal along its longitudinal axis in stepwise fashion relative to a toothed punch, operating the punch between each two successive advancing steps to partially sever the sheet thereby providing parallel rows of openings, said rows of openings being parallel to said longitudinal axis and each opening defined by a series of strands separated by connecting bridges said bridges being substantially perpendicular to the longitudinal axis, and thereafter stretching the expanded metal sheet in said longitudinal direction beyond its elastic limit until the longitudinal axes of the strands in at least some of the rows become substantially longitudinally aligned.

9. A method as defined in claim 8 wherein the punch is shifted laterally a distance other than a whole number multiple of one-half the width of one punch tooth between each two successive operations of the punch.

10. A method as defined in claim 8 wherein the punch is shifted laterally a distance about equal to one-third the width of one punch tooth between each two successive operations of the punch.

11. An electrode for an electrochemical cell, comprising a sheet of expanded metal having openings delimited by strands defining the lateral boundaries of the openings and connecting bridges between the strands defining the forward and rearward boundaries of the openings, the longitudinal axes of all the strands along at least one side of each row of openings being substantially aligned and substantially parallel to all the other aligned rows of strands, the longitudinal axes of said aligned strands extending along the longitudinal direction of the sheet, and a chemically active powder within said openings.

12. An electrode as defined in claim 11 wherein said powder is selected from the class consisting of zinc, silver, nickel, zinc oxide, and silver oxide.

13. A method of making a sheet of expanded metal comprising the steps of advancing sheet metal along its longitudinal axis in stepwise fashion relative to a toothed punch, operating the punch between each two successive advancing steps to partially sever the sheet thereby providing parallel rows of openings, said rows of openings being parallel to said longitudinal axis and each opening defined by a series of strands connected at their ends to connecting bridges said bridges being substantially perpendicular to the longitudinal axis, the strands being arranged at an angle to the longitudinal direction of advance of the sheet, thereafter stretching the expanded metal sheet in said longitudinal direction to cause rotation of the strands about their ends, and continuing said stretching until said rotation ceases and the longitudinal axes of the strands in at least some of the rows become substantially longitudinally aligned.

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