METHOD AND MEANS FOR THE FORMATION OF HERRING-BONE STRUCTURES

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My invention has for its object a method for the fashioning of herringbone structures of the type disclosed in my copending U.S. patent application Serial No. 514,171, filed on June 9, 1955.

My invention includes also means for the manual and mechanical execution of said method. The herringbone structures of the type considered may be defined in a general sense as folded media characterized by a pronounced thickness in folded state, whereby a reduced thickness folded so as to show alternately projections and depressions, the upper and lower ridges defined by which are located on corresponding geometrical enveloping surfaces, so as to form, to either side of the structure, series of herringbone shaped lines, while the elements between the same are almost entirely folded into the desired herringbone structure an almost unlimited number of times, as provided by the possibility of shifting the folds from a position corresponding to a folding showing simple rectilinear parallel folds, into a more complex condition for which the folds assume their zigzag or undulating shape, corresponding to the actual herringbone structure.

Starting from this idea, my improved method consists in arranging the strip of foldable material which is to form the herringbone structure between two malleable, mechanically resistant sheets to which has been previously given the shape of the herringbone structure to be obtained for the strip, said sheets being termed hereinafter the mother sheets. These mother sheets, when completely developed, are superposed in a manner such that the elementary areas forming the herringbone structure register for the two mother sheets throughout the extent of the latter, after which said mother sheets are returned into their herringbone structure through an intermediate stage consisting in forming the simple rectilinear folds, after which a lateral compression is exerted on both ends of the folds and it is finally sufficient to remove the desired herringbone structure formed by the foldable strip out of the mother sheets enclosing it.

It is apparent that the two mother sheets thus resorted to form a sort of deformable mould inside which the strip of material to be shaped into herringbone structure receives its final shape. Whatever may be the shape of the elementary lateral areas forming the herringbone structure considered, the two mother sheets superposed in the manner disclosed remain in contact throughout their extent with the interposition of the strip of material to be folded, the elementary lateral areas of both sheets facing each other, both for the position of complete development.

For the herringbone structure position for which all the joining folds are gathered together, as well as for all the intermediate positions between said extreme positions.

When passing, in particular, from the position corresponding to the presence of simple rectilinear folds to the final herringbone structure position, the positions of the strip of foldable material superimposed between the mother sheets, which occupy the intervals extending between the rectilinear lines of fold along the pleated areas and the broken-lined folds along the herringbone areas, are subjected to a sort of sliding and rolling movement which readily allows the passage from one shape to the other.

Said procedure allows replacing a herringbone forming operation which it is difficult to execute directly, since it implies, in principle, a folding stage, executed simultaneously along two main rectangular directions, by two separate operations, executed in succession: a pleating with large, rectilinear undulations, which forms a very simple stage and an also simple, compression stage, providing for the compression of the undulations thus formed.

The mother sheets may receive at the start the shape of the desired herringbone structure, as a consequence of a pleating executed by hand, for instance, and following the lines drawn on a flat surface corresponding to the development of said structure.

In order that the mother sheets may resist a large number of herringbone forming operations, of the type described, it is, of course, necessary for the material forming it to be perfectly suited for resisting the strains arising through such repeated folding operations. Such materials are to be used, which are flat and comparatively rigid throughout their extent, should be of a material such that they may readily become yielding along the lines of fold formed therein at the beginning of the shaping operation. Furthermore, in the vicinity of the folds and the strains and friction are particularly high, the sheets should not lose any fraction of their natural resilience. Certain very high grade fibrous papers, such as kraft paper, cer-
tain thin and mechanically resistant pasteboards, starch-containing or plasticized fabrics, are fully satisfactory in this respect. The sheets made of such materials allows giving the herringbone shape to several hundred and even several thousand intermediate sheets before being unserviceable, the number of intermediate sheets which may thus be shaped varying according to the rigidity of said intermediate sheets or strips. This provides very large possibilities of practical application, all the more so since it is possible, in accordance with the invention and with the yieldingness of the material to be shaped, to execute the simultaneous herringbone shaping of a plurality of superposed intermediate sheets between the two same mother sheets.

My invention provides also the possibility of cutting all the mother sheets required for the continuous execution of herringbone structures of a predetermined type starting from a single pair of mother sheets which are pleated by hand along the desired outlines. It is generally sufficient, with a view to furthering such a pleating, to moisten slightly the material forming the mother sheets.

The pleating leading to the formation of rectilinear undulations and the compressing step leading to the final herringbone structure may be executed by hand or through mechanical means.

A simple arrangement for manually executing my method includes, in principle, a rectilinear trough with a flat bottom, the size of which corresponds substantially to that of the mother sheets when developed on a flat surface and into which the latter are inserted with the interposition between them of at least one sheet or strip of the material to be fashioned; while maintaining then the superposed sheets in joining relationship by exerting a longitudinal traction thereon, the operator forms first the transverse folds, undulation after undulation, between his hands and, the folds being then gathered, they are compressed in succession by hand through manual action on both ends thereof.

This manual method allows reproducing easily, with an extremely simple and economical implementing and a comparatively low expenditure of labour, a large number of types of herringbone structures in a perfect manner, without any tearing of the material; however, this manual method shows the drawback of straining the operator to a comparatively large extent.

The invention also provides mechanical means for the execution of such methods of forming herringbone structures between mother sheets, while cutting out the fatigue of the operator and allowing, in fact, a still further substantial increase in productivity. For this purpose, the invention includes, more particularly, the execution of a machine adapted to fashion, between mother sheets, herringbone structures forming flat plates of a limited extent and also a machine adapted to shape through the same method curvilinear herringbone structures and, in particular, cylindrical structures.

The machine intended for the fashioning of flat herringbone structures includes chiefly two cylinders having parallel axes cooperating with one another, so as to drive, in a direction perpendicular to the transverse folds of the structure to be obtained, the mother sheets in their flat developed condition, with the interposition of the sheets or strips to be shaped between them. The machine includes further a receiving box located in registry with said cylinders and containing a movable piston against which the system including the mother sheets and the sheets to be shaped therebetween is pleated transversely under the action of the thrust produced by the drive of the cylinders, means for ejecting the pleated system out of the receiving box, a herringbone forming box including inwardly distributed projections corresponding to the undulations of the herringbone structure to be obtained and a movable piston arranged in said herringbone forming box so as to exert a lateral pressure on the corresponding ends of the transverse folds of the pleated system, the wall of the herringbone forming box opposed to said piston being adapted to open at the end of the operation, so as to allow an ejection of the final herringbone structure.

In the case where the machine is to serve for the simultaneous shaping of a plurality of superposed sheets, said machine may advantageously be fed with strips of an unlimited length winding off a corresponding number of rolls arranged in sequence. In such a case, the machine may further include means for ensuring a correct superposition of the strips, means for cutting in said superposed strips, sheets of lengths corresponding to that of the mother sheets and means for guiding the mother sheets and the superposed sheets arranged between them, as they enter the gap between the cylinders of the pleating means.

The machine providing for the fashioning between mother sheets of herringbone structures of a cylindrical shape is designed in accordance with the fact that, as disclosed in my U.S. patent application Serial No. 787,031, filed on January 15, 1959 (now Patent No. 2,950,656, issued on August 30, 1960), relating to an arrangement for the continuous fashioning of developable herringbone structures, the cylindrical herringbone structure includes longitudinal rows of radial folds distributed uniformly along the periphery of the structure, after the manner of star projections, so that the herringbone shaping executed on a cylindrical tube of foldable material consists firstly in a longitudinal pleating operation performed on the original tube, which leads to the transformation of said tube into a prism having a star-shaped cross-section and including as many radial projections as the herringbone structure to be obtained. Starting from this idea, my improved machine includes chiefly a frame of a generally cylindrical shape, along the periphery of which are distributed moveable arms parallel with the axis of the cylindrical frame and the number of which corresponds to the number of projection ribs on the cylindrical herringbone structure to be executed, so as to form a prismatic skeleton adapted to be engaged by a tubular system constituted by two coaxial developed cylindrical mother sheets between which are inserted one or more, also cylindrical sheets to be shaped, said frame being associated with means for holding said tubular system on said arms, in a manner such that each of the concave longitudinal folds of the mother sheets is applied over one of the arms, and means for shifting said arms in parallelism with the frame axis in radial planes converging towards the axis of the frame, so as to transform gradually the tubular system carried by them into a prism having a star-shaped cross-section.

My invention provides also a stretching device adapted to be used in connection with the machine which has just been described, with a view to holding in correct position with reference to one another the folds in the mother sheets of the original tubular system, and to positioning said system on the arms of the machine and, furthermore, an arrangement is provided for producing an axial compression of the star-shaped prism obtained in said machine, so as to transform said prism into the desired cylindrical herringbone structure.

Further features and advantages of my invention will appear in the reading of the further description given hereinafter, reference being made to the accompanying drawings, given as an example and by no means in a binding sense. In said drawings:

FIGS. 1, 2 and 3 are perspective views showing the main stages of the herringbone shaping through the agency of mother sheets, as executed by hand.

FIGS. 4a and 4b are two sections of a diagrammatic elevational view of a machine for shaping between mother sheets of herringbone structures in flat form and the two sections continuing each to either side of the line A—A.

FIGS. 5a and 5b are two sections, corresponding respectively to FIGS. 4a and 4b, of a diagrammatic plan view of the same machine.

FIG. 6 is a vertical cross-section on a larger scale of
the portion of the machine in which the pleating operation is performed and which is bounded in FIG. 4b by the circular dot-and-dash line B, with a partial cross-section through line VI—VI of FIG. 5b.

FIG. 7 is a front view of the machine portion illustrated in FIG. 6, as seen in the direction of the arrow F of the latter.

FIG. 8 is a detail cross-section, also on a larger scale, through line VIII—VIII of FIG. 5b.

FIGS. 9 and 10 are large scale views in the direction of the arrow F of FIG. 5b and illustrating respectively the beginning and the end of the formation of the herringbone structure.

FIGS. 11 and 12 are plan views corresponding respectively to FIGS. 9 and 10.

FIG. 13 is a diagrammatic elevation view of a stretching device to be used in association with a machine adapted to fashion circular herringbone structures.

FIG. 14 is a plan view of a tubular system to which a herringbone shape is to be given, as positioned on the stretching device illustrated in FIG. 13.

FIGS. 15, 16 and 17 are vertical sectional views of a simple machine for the fashioning of circular herringbone structures for different operative positions of the machine parts illustrated.

FIGS. 18, 19 and 20 are plan views of the tubular system to which the herringbone shape is to be given at different stages of the longitudinal pleating procedure corresponding to the positions of the machine parts illustrated in FIGS. 15 to 17.

FIG. 21 shows, with further detail, an element of the machine shown in FIGS. 15 to 17.

FIGS. 22 and 23 are diagrammatic vertical cross-sections illustrating two stages of axial compression of the pleated structure obtained through the agency of the machine illustrated in FIGS. 15 to 17.

FIG. 24 is a plan view of the arrangement adapted to execute the operation described in FIGS. 22 and 23, said arrangement distributing the projecting parts of the structure along the periphery of the latter.

FIG. 25 is a cross-section through line XXV—XXV of FIG. 26 of a practical embodiment of a stretching device, the two halves of said FIG. 25 showing the apparatus respectively in two different operative positions.

FIG. 26 is a plan view corresponding to FIG. 25.

The manual shaping arrangement operating through the use of mother sheets and illustrated in FIG. 1 includes a flat-bottomed trough 1 provided with upstanding lateral edges 2 and 3 and of which the length and the breadth correspond to those of the mother sheets 4 and 5 in their flat condition. The operation of said arrangement is as follows:

One of the mother sheets 4 is laid flat over the bottom of the trough and over it are laid one or more sheets to be shaped, as shown at 6, said sheets having the same size as the mother sheets and over them is positioned the second mother sheet 5.

The system of sheets 4, 5 and 6 is held in joining relationship by a frictional effort exerted at one of its ends and it is pleated first transversely at the rate of one undulation at a time between the operator's hands, as shown in FIG. 2, the operation beginning at the end which is not held fast and continuing gradually up to the other end subjected to the frictional stress.

The folds being gathered, they are compressed then through the agency of a compression stress exerted in succession on the ends of each of the undulations, as shown in FIG. 3. Said operation returns the mother sheets into the herringbone shape given originally to them and which has been transferred accurately to the sheet or sheets 6 inserted between the mother sheets for forming an easy matter to the newly shaped herringbone sheet or sheets from the mother sheets.

I will now describe a machine designed for the mechanical fashioning of flat herringbone structures between mother sheets, in accordance with my invention. Said machine, illustrated as a whole in FIGS. 4a and 4b and 5a and 5b, includes, in the present case, five strip-carrying rolls 7a, 7b, 7c, 7d, 7e fitted in parallelism in carriers 8a, 8b, 8c, arranged on a common pedestal 9 over which said rolls revolve freely. The five strips wound off the rollers are superposed at 10 and they pass together through a small press 11 fitted on the end of a table 12, provided on its downstream side with a cutting blade 13. The press 11 is carried by small rollers 14 and it is urged against a stop, which is not illustrated, by a counterweight 15 running over a slope 16 formed underneath the table 12.

As it passes out of the press 11, the system of strips 10 extends above the table 12. At a predetermined distance beyond the front end of said table opposed to that normally carrying the press 11, there is located, in alignment with the strips 10, a pair of transverse cylinders 17, 18 carried by an intermediate frame 19 and the part played by which will be described hereinafter. Between the table 12 and the cylinders 17, 18 are arranged to either side of the plane along which the strips 10 move two slopes 20 and 21 converging towards the gap between the cylinders 17, 18 and covering the outer surfaces of the mother sheets 22 and 23 forming the mould in which the herringbone structure is to be obtained.

Beyond the cylinders 17, 18 is arranged, on a table 24, a receiving box 25 adapted to be engaged by the structure which has been subjected to a first transverse pleating operation. Said box encloses a piston 26 adapted to hold the folds of the structure in position inside said box and an ejecting piston 27 adapted to move transversely in the box, as shown in FIG. 5b. On the same table 24 is positioned, beyond the receiving box 25, a box 28 for the formation of the actual herringbone folds, which box is provided inwardly alternately on each side with transverse projections 29 and 30 separated by intervals corresponding to those separating the undulations of the herringbone structure to be obtained (FIGS. 9 and 10). Said box 28 is equipped, on one side, with a double piston 31 ensuring transverse compression and ejection of the paper provided, on the other side, with a movable closing panel 32 pivotally secured at 33 (see FIG. 8).

The preceding description shows that the machine includes two entirely separate stations, to wit: a first transverse pleating station and a second herringbone shaping station. These two stations are served each by its own piston 26 or 27 and 28 respectively at O1 and O2 (FIG. 5b). The formation of the herringbone structure is obtained through the following cycle of operative steps:

At the beginning of the cycle, the press 11 occupies a position 11', illustrated in dot-and-dash lines at the front end of the table 12 (FIG. 4b), the superposed sheets 10 being cut at the front of the blade 13 carried by said press at the point b. The workman positioned at O1 takes hold of the sheets 10 at b and releases at the same time the press 11 which is urged rearwardly by its counterweight 15 into its normal operative position illustrated in solid lines at the rear end of the table 12 where an arrangement, which is not illustrated, clamps automatically said press over the sheets 10 fed by the rollers 7a, 7b . . . 7e, the blade 13 lying then at the point a (FIG. 4a). It should be remarked that the spacing between the points a and b is adjusted, so as to be accurately equal to the length of the sheet to be shaped.

The press 11 being anchored on the sheets at a, the workman positioned at O1 draws forwardly the front end of the superposed sheets, until he is able to insert the end of the pack inside the acute angle formed at c between the two mother sheets 22, 23 converging between the slopes 20 and 21 (FIG. 4b). The workman holds fast then between his fingers the system constituted by the mother sheets and the pack of sheets to be shaped between the latter and urges the first line of fold of said
system between the two lips 34 and 35 of the guiding member positioned in front of the input of the cylinders 17 and 18 (FIG. 6). The middle line of fold engages the gap between said two cylinders. Said cylinders, which are interconnected by the two gears 36 and 37, are driven into rotation by a motor, which is not illustrated, through the agency of a belt 38 engaging a pulley 39 rigid with the spindle carrying the lower cylinder 18 (FIG. 7), and the cylinders drive gradually forwardly in their turn the system of mother sheets and sheets to be shaped and pleat it transversely inside the receiving box 25, while making the piston 26 recede slightly, which piston forms a bearing for the structure built up by the folds P thus formed (FIG. 6).

When the press 11 drawn over the table 12 by the traction exerted on the sheets 10 has its blade 13 again in registry with the point b, a releasing device, which is not illustrated, causes the blade 13 to cut the sheets and holds the press fast in the position occupied by it. The cut section of the sheets continues progressing under the action of the cylinders 17, 18.

When the pleating operation is at an end, the operator positioned at O3 lays further mother sheets on the sloping planes 20 and 21 and takes hold of the free end of the sheets 10 at b, so as to begin over again the operation constituting the preceding cycle.

During the pleating cycle, which has just been terminated, the workman positioned at O2 who has found in the receiving box 25 a pleated structure P produced by the preceding cycle proceeds in the following manner, so as to obtain therein the desired herringbone structure. He first seizing a hook 48 located to the front of the input guide 34, 35 for the cylinders 17, 18 (FIGS. 6 and 7), and he draws the hook in the direction of the arrow F, so as to make it enter the empty space provided to this end in registry with the medial section of the system including the cylinders and the guide 34, 35. The workman then releases the folds of the structure with reference to the cylinders 17, 18 and then through actuation of the ejecting piston 27, he urges out of the receiving box 35 the pleated structure P to make it lie on the table 24 at P3 (FIG. 5b). This structure is shifted towards the right-hand side of the drawing by the workman at O2 and it expands and occupies the space P3 of the length of which is substantially equal to that of the herringbone forming box 28.

Upon opening of the panel 32 closing the box 28, the workman at O2 urges the expanded structure P3 in the direction of the arrow F' into the box 26, the distribution of the folds being such that each turn of the box 26 corresponds to a projection 29 or 30 (FIGS. 9 and 11). Having done this and having closed the panel 32, the workman acts on the lateral compressing piston 31. Under the thrust exerted by said piston, the structure assumes gradually the desired herringbone structure and enters finally a position P3 between the distributing projections 29 and 30 (FIGS. 10 to 12).

At the end of the stroke of the piston 31, the workman at O2 opens again the panel 32 and the structure P3 is ejected onto the table 24 in its final herringbone shape. It is sufficient finally to remove the shaped sheets from between the mother sheets and to lay them at 41 on the intermediate frame 19 (FIG. 5b), so that the workman at O2 may take hold of them.

FIGS. 13 to 26 relate to the execution of a machine intended for the fashioning of circular or cylindrical herringbone structures between two mother sheets also of cylinrical shape. I will assume hereinafter, for sake of simplicity of disclosure, that it is desired to obtain a cylindrical herringbone structure with six radial arms. Only FIGS. 25 and 26 relate to the execution of an auxiliary arrangement for a machine adapted to execute a standard cylindrical herringbone structure including a larger number of arms distributed at the periphery of the circular system, for instance a herringbone structure with twenty-two arms.

In principle, and as described hereinafter, the shaping of a cylindrical herringbone structure includes a first longitudinal pleating step for a tubular system 42 (FIGS. 13 and 14) constituted by two completely developed cylindrical mother sheets between which is inserted at least one sheet to be shaped also in its original cylindrical condition, said operative step leading to the formation of a star-shaped prism including the peripheries of the arms as are to be provided on the desired herringbone structure.

In order to hold in its proper shape the original tubular system 42, with a view to positioning it on the machine, I provide advantageously a stretching device, illustrated diagrammatically in FIG. 13. Said device includes as many arms 43 as there are arms to be obtained on the final structure, to wit, six in the example illustrated, said arms 43 being assumed, in the present case, to be pivotally secured together at 44, so that they may be shifted in medial planes. Said arms 43 engage inwardly the convex folds of the tubular system 42 defined hereinabove and, through a suitable operation, they are brought into the position illustrated in FIG. 13, in which position they are parallel and held in their developed condition and in exact registry with reference to each other the convex folds of the mother sheets. The tubular system shows then the shape illustrated in plan view and old view 14, 44, 45, 46 designating the two mother sheets and 47 the sheets to be shaped, which lie between the latter and 43 the arms of the stretching device.

The machine intended for the reception of the system thus held in position includes, as shown in FIGS. 15, 16 and 17, a frame 48 of a generally cylindrical shape, along the axis of which is arranged a stationary upright 49; over the latter is slidably fitted a sleeve 50 adapted to move vertically. To said sleeve are connected links such as 51 and 52 forming deformable parallelogramms with as many vertical arms 53 as the cylindrical structure to be shaped is to include radial arms, six in the example illustrated.

The arms 53 are connected furthermore with the stationary sections 48a and 48b of the frame 48 through the links 54 and 55. It will thus be readily understood that when the sleeve 50 slides over the upright 49 under the action of its weight and, if required, of springs or the like control means, the different links are subjected to a movement urging the arms 53 nearer the central axis of the machine through convergent movements, said arms remaining in parallelism with one another as clearly apparent from inspection of FIGS. 15, 16 and 17.

At their upper ends projecting above the frame 48, the arms 53 carry the tubular system 42 which is positioned through the agency of the stretching device 43, and they are provided with shoulders 53a on which said system rests. Said positioning is executed in a manner such that each concave fold of the tubular system 42 stands in registry with an arm 53, as clearly apparent from inspection of the diagrammatic plan view of FIG. 18.

To the rear of each arm 53 is fitted a brush such as 56 constituted, for instance, by nylon bristles, secured to a carrier 57 and the part played by which consists in holding the concave folds of the tubular system 42 in permanent contact with the arms 53, so that said folds may accompany the arms 53 during their converging movement described hereinabove, in spite of the resistance opposed by the sheets to be pleated which are inserted between the mother sheets. The use of brushes for this purpose is justified by the fact that the compound folds of the tubular system are not exactly rectilinear, but form an allowable medium between the rectilinear ridge of a prism and the zigzag shaped folds of a cylindrical herringbone structure.

The brush bristles match the irregular shape of said folds, whereas blades or the like rigid members would be inadequate. In practice, however, the brush 56–57...
corresponding to each arm 53 is fitted slidingly, as illustrated in the detail view of FIG. 21, on a support 58 rigid with the arm 53 and its position is controlled by pneumatic pistons.

When the tubular system 42 is positioned over the arms 53 of the machine and the brushes 56 have been brought near it under the action of the corresponding pneumatic pistons, so as to properly clamp said system in registry with the folds, the sleeve 50 is lowered over the upright 59, which constrains the tubular system to assume gradually the shape of a prism with a star-shaped cross-section, as shown in FIGS. 19 and 20.

When the sleeve 50 arrives at the end of its downward travel and the shape illustrated in FIG. 20 is obtained, the pleating into a star-shape is at an end. The whole pleated system is then taken out of the machine and set in a fold distributor similar as that illustrated in FIGS. 22 to 24. Said fold distributor includes a cylindrical body provided along its inner periphery with a number of guiding members 60 equal to the number of longitudinal folders in the structure. This fold distributor is caused to exert a compressional action in the direction of the axis of the structure, as illustrated diagrammatically in FIGS. 22 and 23, so as to obtain a collapse of the different folds of the mother sheets, and, at the end of its stroke, the whole system has assumed the shape illustrated in FIG. 24 and corresponding to the desired herringbone structure.

For the removal of the herringbone shaped sheets out of the mother sheets, it is sufficient to develop the whole arrangement and to return it into the original tubular shape. By allowing the herringbone shaped sheets to be folded along their folds, said sheets return readily into their cylindrical herringbone shape.

The method described is of particular interest for the formation of filtering cartridges made of nylon fabric, since nylon fabric may be pleated and unfolded almost indefinitely without any damage to it. In this case, the folds may be secured and fixed by heating in a kiln at about 120° C. the structure compressed into the condition illustrated in FIG. 24. The herringbone shaped elements made of nylon are taken out of the mother sheets only when they have been cooled down to room temperature.

FIGS. 25 and 26 illustrate a practical embodiment of a stretching device adapted to be used in the fashioning of a cylindrical herringbone structure including, for instance twenty-two projecting arms. Said stretching device includes twenty-two arms such as 61 distributed uniformly inside a framework and, at the end of their free foot 62 mounted on the carrier feet 63 and annular member terminating with an inner annular bead 64 to which said arms are pivotally secured through their eyes 65.

Above the annular member 62, each arm 61 carries a lateral projection 61f forming an abutment for the position of the tubular system to be shaped, as illustrated in dotted-and-dash lines at 42.

Underneath the annular member 62, each arm 61 extends into a section 61f folded into the shape of a U engaging an annulus 66 adapted to be shifted vertically upon actuation of the handle 67 carrying it.

At the beginning of the stretching operation, the annulus 66 is in its uppermost position, illustrated on the left-hand side of FIG. 25 and, consequently, the arms 61 slope towards the axis of the apparatus, which allows them to carry readily the tubular system 42 formed by the mother sheets and the sheets to be shaped carried between the latter.

Upon lowering of the annulus 66 through the agency of the handle 67, the arms 61 are set in a substantially vertical position, as illustrated on the right-hand side of FIG. 25, which position corresponds to the complete development of the tubular system 42.

When used in the claims, a sheet described as forming a "herringbone pattern" shall be construed to refer to a sheet having ruled elementary surfaces (viz., a geometrical figure which can be generated by a straight line) which join each other along lines having points at which they change direction and at each of which points border lines of at least four of said elementary surfaces converge, the sum of the angles formed on said surfaces between said border lines at each of said points being equal to 360°. In its simplest form, said herringbone pattern will be comprised of a plurality of surfaces in the form of parallelograms, trapeziums or equal or symmetrical triangles, or by combinations of these. Such a pattern may also be formed of undulating surfaces with substantially parallel, curvilinear ridges.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. A method for forming a developable herring-bone pattern in a sheet of foldable material comprising the steps of placing at least one of said sheets between two developed mother sheets which have previously been shaped into said herring-bone pattern; each of said mother sheets being made of a mechanically resistant material which may be developed and returned to its herring-bone pattern a plurality of times without rupture; said mother sheets being sandwiched about said sheet of foldable material so that the pattern of one mother sheet mates with the pattern of the other; returning said mother sheets to their undeveloped, herring-bone pattern by first moving one pair of adjacent terminal portions of said mother sheets towards the other pair of adjacent terminal portions of said mother sheets in a first linear path to restore the folds in said mother sheets which are transverse to said linear path and then exerting a compressing force on the other two pairs of terminal portions of said mother sheets to urge said pairs toward one another to restore the folds in said mother sheets which are substantially perpendicular to said first-mentioned folds; and removing said mother sheets from the folded intermediate sheet.

2. A method for forming a developable herring-bone pattern in a sheet of foldable material comprising the steps of placing at least one of said sheets between two developed mother sheets which have previously been shaped into said herring-bone pattern; each of said mother sheets being made of a mechanically resistant material which may be developed and returned to its herring-bone pattern a plurality of times without rupture; said mother sheets being sandwiched about said sheet of foldable material so that the pattern of one mother sheet mates with the pattern of the other; returning said mother sheets to their undeveloped, herring-bone pattern by first moving one pair of adjacent ends of said mother sheets towards the other pair of adjacent ends in a direction longitudinally of said sheet to restore the substantially transverse folds in said mother sheets and then exerting a compressing force on the longitudinal edges of said mother sheets to urge said edges towards one another to restore the substantially longitudinally extending folds in said mother sheets; and removing said mother sheets from the folded intermediate sheet.

3. A method as defined in claim 2 in which a plurality of sheets of foldable material are placed between said mother sheets and simultaneously folded in the manner set forth.

4. Apparatus for forming a developable herring-bone pattern in a sheet of foldable material by interposing at least one said sheet between two developed mother sheets which have previously been shaped into said herring-bone pattern...
pattern and which have been sandwiched about said sheet of foldable material so that the pattern of one mother sheet mates with the pattern of the other, comprising: means for feeding as a unit the sandwich formed by said mother sheets and sheet of foldable material in a direction substantially perpendicular to the transverse folds to be formed in the mother sheets when returned to their undeveloped condition, said feeding means being of such configuration that it does not itself impart folds to said sandwich; a first enclosure adjacent said feeding means and positioned to receive the said sandwich within its confines; said first enclosure having an abutment against which the sandwich material which has been fed into said first enclosure abuts, whereby said sandwich will be pleated transversely along the transverse folds of the mother sheets under the action of the thrust produced by said feeding means; a second enclosure two opposing surfaces of which are provided internally with a plurality of substantially parallel rows of centrally directed projections; the projections of one surface being staggered with respect to the projections of the opposing surface; said projections being adapted to be positioned within the concavities of the transverse pleats of said sandwich when the latter is positioned within said second enclosure with its transverse pleats substantially parallel to said rows of projections; and means associated with said second enclosure for exerting lateral pressure on the ends of the transverse pleats of said sandwich.

5. The apparatus defined in claim 4 wherein the abutment in said first enclosure is yielding, said abutment yielding in the direction of the sandwich feed as additional sandwich material is fed into said first enclosure to permit additional sandwich to be fed into said first enclosure.

6. The apparatus defined in claim 5 wherein said feeding means comprises a plurality of substantially smooth cylinders having parallel axes.

7. The apparatus defined in claim 5 wherein said second enclosure has a wall which may be opened to permit the finally folded herring-bone structure to be ejected from said second enclosure.

8. The apparatus defined in claim 5 wherein the height of said first enclosure is approximately equal to the height of the transversely pleated sandwich and the height of said second enclosure is approximately equal to the height of the finally herring-bone folded sandwich corresponding to the number of concave ridges of the pleated cylinder to be formed; said movable arms forming a prismatic skeleton adapted to be inserted within the tubular system formed by said coaxially arranged foldable material and mother sheets in their developed condition; means for holding said tubular system about said movable arms in a manner such that each of the longitudinal concave folds of said mother sheets will engage one of said arms; and means for moving said arms in parallelism with one another in radial planes converging towards the center of the circle about which said arms are mounted, thereby transforming the tubular system into a cylinder having a star-shaped cross-section.

12. Apparatus as defined in claim 12 wherein said holding means comprises brushes urging the concave folds of said mother sheets against said arms.

13. Apparatus as defined in claim 12 wherein said feeding means comprises for ejecting the transversely pleated sandwich from said first enclosure.

14. The apparatus defined in claim 12 wherein said means for ejecting the transversely pleated sandwich from said first enclosure is a transversely movable piston.

15. Apparatus for forming pleats in a sheet of foldable material by interposing at least one said sheet between two developed mother sheets which have previously been folded into said pleated pattern and which have been sandwiched about said sheet of foldable material so that the pattern of one mother sheet mates with the pattern of the other, comprising: means for feeding as a unit the sandwich formed by said mother sheets and sheet of foldable material in a direction substantially perpendicular to the folds to be formed in the mother sheets when returned to their undeveloped condition, said feeding means being of such configuration that it does not itself impart folds to said sandwich; an enclosure adjacent said feeding means and positioned to receive said sandwich within its confines; said enclosure having an abutment against which the sandwich material which has been fed into said enclosure abuts, whereby said sandwich will be pleated transversely along the transverse folds of the mother sheets under the action of the thrust produced by said feeding means, said abutment being yielding in the direction of the sandwich feed as additional sandwich material is fed into said enclosure to permit additional sandwich to be fed into said enclosure.
material which has previously been transformed into a longitudinally pleated cylinder of star-shaped cross-section by coaxially interposing a cylinder of said foldable material between two mating mother cylinders which have previously been shaped into said herring-bone pattern and which have been preliminarily formed into coaxial cylinders of star-shaped cross-section, comprising: a plurality of rigidly mounted, parallel elongated guide members disposed at the periphery of a circle whose diameter is approximately that of a circle circumscribed about said star-shaped coaxially arranged mother sheet-foldable material cylinder combination, the number of said guide members being equal to the number of arms of said star-shaped combination; and means for compressing axially said star-shaped coaxially arranged combination while the arms of said combination remain positioned within their respective guide members.

22. Apparatus as defined in claim 21 wherein said guide members are elongated channel members; the open portion of the U formed by each of said channel members facing towards the center of the circle along the periphery of which said channel members are mounted.

23. Apparatus as defined in claim 22 wherein said channel members are mounted axially along the inner wall portion of a hollow cylinder.

24. A method of forming a developable, cylindrically shaped herring-bone pattern in a cylinder of foldable material comprising coaxially interposing said cylinder between two developed, mating mother cylinders which have previously been shaped into said herring-bone pattern; each of said mother cylinders being made of a mechanically resistant material which may be developed and returned to its herring-bone pattern a plurality of times without rupture; forming the cylinder system including said mother sheets and interposed cylinder of foldable material into a cylinder of star-shaped cross-section; and axially compressing said star-shaped cylinder system while preventing the arms of said cylinder system from moving laterally away from the position they occupied before said axial compression step a distance greater than approxi-

mately one-half the breadth that the terminal portion of said arms will have when said cylinder system has been fully formed into the desired herring-bone pattern.

25. A method for forming a developable herring-bone pattern in a foldable material comprising the steps of placing at least one piece of said foldable material between two developed mother forms which have previously been shaped into said herringbone pattern; each of said mother forms being made of a mechanically resistant material which may be developed and returned to its herringbone pattern a plurality of times without rupture; said mother forms being sandwiched about said piece of foldable material so that the pattern of one mother form mates with the pattern of the other; returning said mother forms to their undeveloped, herring bone pattern while still sandwiched about said piece of foldable material by first restoring the folds in said mother forms along lines all of which are substantially parallel to one another and then restoring the folds in said mother forms which are substantially perpendicular to said first mentioned folds; and removing said mother forms from the folded intermediate material.

26. A method as defined in claim 25 wherein said second mentioned folds are restored through the application of a compressive force on said mother forms along lines substantially parallel with said first mentioned folds.

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