HINGED THREE-DIMENSIONAL STRUCTURE FORMED WITH TWO-DIMENSIONAL SHEET OF MATERIAL

Inventors: Max W. Durney, San Francisco, CA (US); Radha Vaidyanathan, Los Altos, CA (US); Ryan Lam, San Mateo, CA (US)

Correspondence Address: MORGAN, LEWIS & BOCKIUS, LLP ONE MARKET SPEAR STREET TOWER SAN FRANCISCO, CA 94105 (US)

Assignee: Industrial Origami, Inc., San Francisco, CA (US)

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Abstract

A substantially two-dimensional sheet material is configured for bending along a bend line to form a three-dimensional structure having a hinge along the bend line. The sheet material includes a substantially two-dimensional in a region in which a bend is to be made, and a plurality of displacements in a thickness direction of the sheet material along opposing sides of the bend line, each displacement having a sheared edge extending between end portions thereof and substantially parallel to the bend line. The adjacent sheared edges overlap one another with respect to the bend line to form a hinge structure therebetween extending along the bend line, the hinge structure having hinge ends that conform in shape with the end portions. The hinge structure is dimensioned and configured for multiple bend and unbend cycles thereby providing a monolithic hinge connecting opposing panels of the sheet material on opposing sides of the bend line. A method of preparing and using the hinged three-dimensional structure is also disclosed.
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CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 60/974,468 filed Sep. 22, 2007, entitled Hinged Three-Dimensional Structure Formed With Two-Dimensional Sheet Of Material, the entire contents of which is incorporated herein for all purposes by this reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] This invention relates, in general, to two-dimensional sheet materials configured to form hinged three-dimensional structures and methods for their use.
[0004] 2. Description of Related Art
[0005] Various methods of preparing sheet materials for precision folding along a desired bend line have been developed. For example, U.S. Pat. Nos. 6,877,349, 6,877,349, 7,032,426, 7,152,449 and 7,152,450 describe various methods of preparing and folding sheet materials for forming three-dimensional objects having relatively high dimensional tolerances from substantially planar two-dimensional sheets.
[0006] The folding-structures shown and described in the above patents promote so-called edge-to-face engagement and other phenomena to facilitate folding along a desired bending line. For example, as discussed in the above-mentioned '450 patent, displacements may be formed to facilitate bending along a desired bend line.
[0007] The three-dimensional objects formed may be enclosures and other structural items having an interior and/or other form of compartment. In many instances, periodic access to the interior may be necessary for assembly and construction, maintenance and services, and/or other purposes. Generally, disassembly to some degree is necessary in order to access the interior. Alternatively, a door or other discrete hinged member may be provided to ease access. Disadvantageously, such a member requires a discrete door, a discrete hinge, and other parts and fasteners which increase part count, complicates assembly and generally requires more time, space and labor.
[0008] It would therefore be useful to provide a sheet of material having bend-controlling structures that not only facilitate bending for assembly, but also provide an integral hinge structure to reduce part count, simplify assembly, and facilitate access.

BRIEF SUMMARY OF THE INVENTION

[0009] One aspect of the present invention is directed to a method of preparing a substantially two-dimensional sheet material for bending along a bend line to form a three-dimensional structure having a hinge along the bend line. The method may include one or more of the following steps: obtaining a sheet material that is substantially two-dimensional in a region in which a bend is to be made; and forming a plurality of displacements in a thickness direction of the sheet material along opposing sides of the bend line, each displacement having a sheared edge extending between end portions thereof and substantially parallel to the bend line. Adjacent sheared edges overlap one another with respect to the bend line to form a hinge structure therebetween extending along the bend line, the hinge structure having hinge ends that conform in shape with the end portions. The hinge structure is dimensioned and configured for multiple bend and unbend cycles thereby providing a monolithic hinge connecting opposing panels of the sheet material on opposing sides of the bend line.
[0010] The obtaining step may be accomplished by obtaining a mild steel sheet material. The forming step may be accomplished by forming the displacement such that the sheared edge may be a distance from the bend line that may be at least 75% the thickness ("T") of the sheet material. The forming step may be accomplished by forming the displacement sheared edges with the substantially linear portion extending between curved portions, and such that adjacent sheared linear portions and curved portions overlap one another for a distance that may be at least approximately 6T.

The forming step may be accomplished by forming displacement faces opposing the displacement sheared edges, the method may further include the step of bending one of the opposing panels relative to the other opposing panel about the bend line to produce edge-to-face engagement between at least a portion of the sheared edges and a portion of the respective displacement faces.

[0011] The method may further include the step of bending one of the opposing panels about the bend line relative to the other opposing panel. The method may further include the step of bending one of the opposing panels about the bend line relative to the other opposing panel at least 25 times, preferably at least 35 times, and most preferably at least 50 times. The method may further include the step of assembling the sheet material into a three-dimensional structure wherein one of the opposing panels provides a hinged panel for the three-dimensional structure that can be opened and closed.
[0012] Another aspect of the present invention is directed to a substantially two-dimensional sheet material configured for bending along a bend line to form a three-dimensional structure having a hinge along the bend line. The sheet material includes a sheet material substantially two-dimensional in a region in which a bend is to be made, and a plurality of displacements in a thickness direction of the sheet material along opposing sides of the bend line, each displacement having a sheared edge extending between end portions thereof and substantially parallel to the bend line. The adjacent sheared edges may overlap one another with respect to the bend line to form a hinge structure therebetween extending along the bend line, the hinge structure having hinge ends that conform in shape with the end portions. The hinge structure is dimensioned and configured for multiple bend and unbend cycles thereby providing a monolithic hinge connecting opposing panels of the sheet material on opposing sides of the bend line.

[0013] The sheet material may be mild steel. The sheared edge may be a distance from the bend line that may be at least 75% the thickness ("T") of the sheet material. The substantially linear portion may extend between curved portions, and wherein adjacent sheared linear and curved portions overlap one another for a distance that may be at least approximately 6T.

[0014] The sheet material may further include displacement faces opposing the displacement sheared edges, the
displacements configured to produce edge-to-face engagement between at least a portion of the sheared edges and a portion of the respective displacement faces while bending one of the opposing panels relative the other opposing panel about the bend line. The hinge structure may be configured to bend and unbend at least 25 times. The hinge structure may be configured to bend and unbend at least 50 times.

In other embodiments, a three-dimensional structure may include the sheet materials described above, wherein one of the opposing panels forms a hinged access cover for access to a portion of the three-dimensional structure. The three-dimensional structure may be a box, and the hinged access cover may be a lid providing access to an interior portion of the three-dimensional structure.

A further aspect of the present invention is directed to a substantially two-dimensional sheet material configured for bending along a bend line to form a three-dimensional structure having a hinge along the bend line. The sheet material includes a sheet material substantially two-dimensional in a region in which a bend is to be made, and a plurality of tongues positioned along opposing sides of the bend line, each tongue having a face directed toward the bend line and extending substantially parallel to the bend line, the tongue extending between end portions diverging away from the bend line. The adjacent faces may overlap one another with respect to the bend line to form a hinge structure therebetween extending along the bend line, the hinge structure having hinge roots that conform in shape with the end portions. The hinge structure may be dimensioned and configured for multiple bend and unbend cycles thereby providing a monolithic hinge connecting opposing panels of the sheet material on opposing sides of the bend line.

The methods and sheets of the present invention have other features and advantages which will be apparent from or are set forth in more detail in the accompanying drawings, which are incorporated herein for all purposes, and the following Detailed Description of the Invention, which together serve to explain certain principles of the present inventions.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a plan view of an exemplary two-dimensional sheet material dimensioned and configured to form a hinged three-dimensional structure in accordance with various aspects of the present invention, and FIG. 1B is an enlarged detail thereof.

FIG. 2 is an isometric view of a portion the sheet material of FIG. 1, and an enlarged detail thereof, illustrating displacements in the sheet material along a bend line forming hinge structures therebetween in accordance with various aspects of the present invention.

FIG. 3 is an isometric view of the sheet material of FIG. 1 showing hinges thereof in a bent position.

FIG. 4 is an isometric view of the sheet material of FIG. 1 showing sides thereof in a bent position.

FIG. 5 is an isometric view of the sheet material of FIG. 1 showing a top thereof in a bent position.

FIG. 6 is an isometric view of the sheet material of FIG. 1 showing the top in a closed position, thereby forming a three-dimensional structure in the form of an enclosure.

FIG. 7 is an isometric view of the sheet material of FIG. 1 showing the top in an opened position, thereby allowing access to the interior of the three-dimensional structure.

FIG. 8 is an isometric view of a portion of the sheet material of FIG. 1, and an enlarged detail thereof illustrating the hinge structures after the sheet material has been bent along the bend line.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to various embodiments of the present inventions, examples of which are illustrated in the accompanying drawings and described below. While the inventions will be described in conjunction with exemplary embodiments, it will be understood that the present description is not intended to limit the inventions to those exemplary embodiments. On the contrary, the inventions is/are intended to cover not only the exemplary embodiments, but also various alternatives, modifications, equivalents and other embodiments, which may be included within the spirit and scope of the invention as defined by the appended claims.

Turning now to the drawings, wherein like components are designated by like reference numerals throughout the various figures, attention is directed to FIGS. 1A and B and FIG. 2 which disclose an exemplary two-dimensional (2D) sheet material 30 that has been dimensioned and configured to form a three-dimensional (3D) structure in the form of an enclosure 32 having a hinged access cover 33. As described in the below-mentioned patents and patent applications, there are numerous applications in which 2D sheet materials can be formed into 3D structures.

The depiction of an enclosure is merely exemplary; the teachings of the present inventions for precision bending are also applicable to the production of numerous other 3D structures having hinged panels including, but not limited to, electronic component chassis, automotive components, transport components, construction components, appliances parts, track components, RF shields, HVAC components, aerospace components, and more. That is, the teachings of the present application are applicable to a wide variety of 3D products and structures that are formed by folding 2D sheet materials, and which would benefit with the provision of a hinged access cover. Such 3D structures may also benefit in that the present invention would allow reducing the 3D structures to their flat forms to facilitate repackaging and reshipping. Such features would be particularly suited for producing reusable shipping containers and the like.

The sheet material is formed of a non-compressible material. Suitable materials include relatively ductile materials such as metal and the like, including but are not limited to mild steel, raw and treated steels such as a galvanized steel, stainless steel, aluminum, and alloys thereof.

Sheet material 30 includes a plurality of bending structures 35 formed in the sheet material that are positioned along bend lines 37 in a manner similar to that described in the above-mentioned patents and patent applications. In the illustrated embodiment, the bend lines are configured to define enclosure sides 39 and enclosure ends 40 extending from an enclosure base 42 as well as enclosure sides 39 extending from access cover 33. The bending structures are formed and oriented to allow precise folding of the sheet material along the bend lines to ultimately position the base, sides ends and access cover in a desired relationship to form the 3D enclosure. One will appreciate that the number, position, and relative orientation of the bending structures and bend lines will vary depending upon the desired shape of the desired 3D structure.

In the illustrated embodiment, the bending structures 35 extend along one side of bend lines 37 to facilitate bending therealong in order to bend the 2D sheet material into a 3D structure, as shown in FIG. 1A. One will appreciate that the bending structures may be configured opposing sides of the bend lines to facilitate bending, as described in the above-mentioned patents and patent applications. In the exemplary embodiment, the bending structures are displacements, however, one will appreciate that other bending structures may be utilized such as the slits, displacements, grooves and/or other bending structures described in the above-mentioned patents and patent applications.

In accordance with the present inventions, certain bend lines may be configured to serve as a hing monolithically formed with the remainder of the sheet material. For example, the exemplary embodiment includes one hinged bend line 44 that is configured to serve as a hinge 46 allowing access cover 33 to be bent back and forth multiple times thus providing enclosure 32 with a hinged access cover allowing access to the interior of the enclosure (see, e.g., FIG. 5, FIG. 6 and FIG. 7). One will appreciate that the sheet material may be provided with one, two, three or more hinged bend lines should multiple hinged panels be desired. In addition, the 2D sheet materials may be provided with one or more hinged punch-outs which would allow local access. For example, hinged bend line 44 is configured to serve as a hinge 46 allowing knockout panel to similarly be bent back and forth.

Hinged bend line 44 includes displacements 47 located on either side of hinged bend line 44. The displacements, in many respects, are similar to those described in the above-mentioned patents and applications. For example, each displacement 47 includes a tongue 49 which is displaced from the overall planar surface of sheet material 30. An exemplary embodiment of the tongue is shown in FIG. 2 and FIG. 1B, the former being a top view showing how tongue 49 is displaced above the overall planar surface of sheet material, while the latter figure is a bottom view showing the depression into the sheet material formed by the displacement of the tongue.

The exemplary tongue extends substantially parallel to the planar portion of the sheet material, and remains connected to the remainder of the sheet material by an inclined transition zone 51. The flat and parallel configuration of the exemplary tongue may promote tool life and other advantages, however, one will appreciate that the tongue need not be flat and/or exactly parallel to the remainder of the sheet material. Opposite transition zone 51 is a sheared face 53 extending along a length of displacement 47. In the exemplary embodiment, the sheared face has a relatively straight central portion 53' and curved end portions 53'' that diverge away from the bend line. The displacements may be formed by stamping, punching, roll forming and/or other suitable means similar to those discussed in the above mentioned patents and applications.

While displacements 47 along hinged bend line 44 may have a similar general configuration as displacements utilized elsewhere on the sheet material, the location and placement of displacements 47 relative to hinged bend line and relative to another is particularly suited to serve as hinge 46. In particular, displacements 47 are positioned on alternating sides of hinged bend line 44 as shown in FIG. 1A and FIG. 1B. More particularly, displacements 47 are spaced away from the hinged bend line in an overlapping fashion relative to adjacent displacements. Preferably, the length of overlap is greater than approximately 6 to 7 times the thickness ("T") of the sheet material. Increasing the length of overlap distributes axial torsion over a greater length and thus provides a good hinge geometry for various applications.

Also, the displacements are preferably located a distance from the hinged bend line that is at least approximately 75% to 100% to 125% the thickness of the sheet material, which corresponds to a jog ("J") distance between overlapping of approximately 1.5T to 2T. In some embodiments, the jog may be as wide as 3T or 4T. Such placement allows fabrication using otherwise conventional stamping, punching and roll-forming techniques.

Such configuration of the displacements generally define hinge structures 54 which extend between overlapping portions of adjacent displacements 47. A portion of the hinge structure extends long across hinged bend line 44 interconnecting opposing panel portions, and in the case of the exemplary embodiment, interconnecting enclosure end 40 to access cover 33. In addition, the hinge structure includes a diverging portion or root 56 that diverges away from the bend line which is formed by and conforms in shape with curved end portion 53' of the sheared face. Also, the posture of the root after folding is largely formed by its contact with the adjacent displacement 47. Preferably, the curved end portion has a relatively large radii of curvature which serves as a stress reducer to distribute stress at the ends of hinge structure 54. The radii of curvature of curved end portion 53' is preferably greater than the thickness of the sheet material, preferably two or three times greater than the thickness of the sheet material, and more preferably approximately three times the thickness or more.

The curved end portion serves to increase the cross-sectional area of the hinge structure as it connects to the remainder of the sheet material. Such configuration is believed to distribute torsional stresses within the hinge structure during bending (and unbending), which torsional stresses are schematically illustrated as arrows "T" in FIG. 1B. In addition, such configuration is believed to realign material stresses at the end of the hinge structure with the adjacent material of the remainder of the sheet, which material stresses are schematically illustrated as arrows "B" FIG. 1B.

It has been demonstrated that such configuration significantly improves the number of bending/unbending
cycles the hinge structure can withstand without failure. For example, exemplary configuration of mild steel sheet metal incorporating the hinge structure is capable of withstand 25 or more bending/unbending cycles without failure, and in some instances, greater than 50 cycles without axial shear across and/or other propagation of shear vicinal the hinged bend line. Preferably the hinges are configured to withstand at least 35 cycles, more preferably at least 45 cycles.

[0041] Such a configuration may also facilitate "strap" behavior that subjects the roots 56 of sheet material immediately adjacent the large-radius ends to tension and torsion (see, e.g., arrows "B" in FIG. 1B). The roots may also serve to facilitate precision bending along the bend line in that they appear to promote bend-assisting tension and torsion in a direction that intersects the bend line.

[0042] Briefly, the folding of the above-described sheet materials is largely similar to the methods discussed extensively in the above-mentioned patent applications and patents. The main difference is, upon completion of folding, hinge structures 54 allow repeated bending and unbending along hinged bend line 44 without material failure for certain number of cycles that can be "designed" in the structure by varying certain parameters including the jog (e.g., hinge width) and the amount of overlap (e.g., hinge length).

[0043] Turning now to FIG. 3 through FIG. 7, a method of folding 2D sheet material into a 3D structure may now be described. Exemplary sheet material 30 is provided with a number of assembly side flanges 58 and an access cover flange 60. The side flanges are dimensioned and configured to secure the sides and ends to one another once the sheet material has been bent along its respective bend lines. In the exemplary embodiment, the side flanges and the assembly side flanges are provided with monolithically formed cooperating mating means, similar to that described in U.S. patent application Ser. No. 11/386,463 (now Pub. No. 2006/0277965), the entire contents of which application is incorporated herein for all purposes by this reference. Access cover flange 60 is dimensioned and configured with similar mating means located on the opposing enclosure end 40. One will appreciate that other suitable mating means may be utilized, and that no mating means need be provided if so desired.

[0044] Preferably, the side and panel flanges are bent by stamping, punching, press-rolling or other suitable means, resulting in the orientation shown in FIG. 3. One will appreciate, however, that bending structures may be provided to facilitate bending of such flanges into position.

[0045] The enclosure sides 39 and enclosure ends 40 may then be bent relative to the enclosure base 42, as shown in FIG. 4 and FIG. 5. As the sides and ends are folded into position, the cooperating mating means will engage thereby securing side flanges 58 to the enclosure sides 39. Alternatively, the side flanges may be secured to the enclosure sides by well known fastening means.

[0046] Finally, access cover 33 may be folded about hinge bend line 44 such that the access cover pivots down to its closed position, as shown in FIG. 6. Preferably, access cover flap 62 is dimensioned and configured to cooperate with mating means provided on the opposing enclosure end 40 to securely hold the access cover in its closed position. While such mating means may be self-locking, it may be preferable to forgo such a self-locking configuration in order to ease reopening of the access cover. Alternatively, the access cover flap may be secured to the opposing enclosure end with well known fastening means.

[0047] As desired, access cover 33 may be reopened, as shown in FIG. 7, to allow access within the enclosure. For example, in the case that enclosure 32 is an electrical component enclosure, it may be desirable to access the interior of the enclosure periodically. Hinge 46 allows such access while eliminating the need for a discrete hinge coupling the access cover to the remainder of the enclosure, and thus reduces part count and assembly costs and complexity.

[0048] Turning back to FIG. 1A, knockout panel 33 may be utilized in a similar manner as the access cover. In addition, the 2D sheet materials may be provided with one or more knockouts-outs 61, monolithically formed tabs interconnecting a remote end of panel 33 with the remainder of the sheet. Unlike conventional punch-out panels which become discrete members once the tabs are broken, the panel 33 remains connected to the remainder of the sheet material via monolithically formed hinge 46.

[0049] For convenience in explanation and accurate definition in the appended claims, the terms "up" or "upper", "down" or "lower", "inside" and "outside" are used to describe features of the exemplary embodiments with reference to the positions of such features as displayed in the figures.

[0050] The foregoing descriptions of specific exemplary embodiments of the present inventions have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teachings. The exemplary embodiments were chosen and described in order to explain certain principles of the invention and their practical application, to thereby enable others skilled in the art to make and utilize various exemplary embodiments of the present inventions, as well as various alternatives and modifications thereof. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.

What is claimed is:
1. A method of preparing a substantially two-dimensional sheet material for bending along a bend line to form a three-dimensional structure having a hinge along the bend line, the method comprising:
   - obtaining a sheet material that is substantially two-dimensional in a region in which a bend is to be made; and
   - forming a plurality of displacements in a thickness direction of the sheet material along opposing sides of the bend line, each displacement having a sheared edge extending between end portions thereof and substantially parallel to the bend line, wherein adjacent sheared edges overlap one another with respect to the bend line to form a hinge structure therebetween extending along the bend line, the hinge structure having hinge ends that conform in shape with the end portions;
   - wherein the hinge structure is dimensioned and configured for multiple bend and unbend cycles thereby providing a monolithic hinge connecting opposing panels of the sheet material on opposing sides of the bend line.

2. The method of claim 1, wherein the obtaining step is accomplished by obtaining a mild steel sheet material.

3. The method of claim 1, wherein the forming step is accomplished by forming the displacement such that the sheared edge is a distance from the bend line that is at least 75% the thickness ("T") of the sheet material.
4. The method of claim 3, wherein the forming step is accomplished by forming the displacement sheared edges with the substantially linear portion extending between curved portions, and such that adjacent sheared linear portions and curved portions overlap one another for a distance that is at least approximately 6T.

5. The method of claim 1, wherein the forming step is accomplished by forming displacement faces opposing the displacement sheared edges, the method further comprising the step of bending one of said opposing panels relative the other opposing panel about the bend line to produce edge-to-face engagement between at least a portion of the sheared edges and a portion of the respective displacement faces.

6. The method of claim 1, further comprising the step of bending one of said opposing panels about the bend line relative to the other opposing panel.

7. The method of claim 1, further comprising the step of bending one of said opposing panels about the bend line relative to the other opposing panel.

8. The method of claim 7, further comprising the step of bending and unbending said one opposing panel about the bend line relative to the other opposing panel at least 10 times.

9. The method of claim 1, further comprising the step of assembling the sheet material into a three-dimensional structure wherein one of said opposing panels provides a hinged panel for the three-dimensional structure that can be opened and closed.

10. A substantially two-dimensional sheet material configured for bending along a bend line to form a three-dimensional structure having a hinge along the bend line, the sheet material comprising:

a sheet material substantially two-dimensional in a region in which a bend is to be made; and

a plurality of displacements in a thickness direction of the sheet material along opposing sides of the bend line, each displacement having a sheared edge extending between end portions thereof and substantially parallel to the bend line;

wherein adjacent sheared edges overlap one another with respect to the bend line to form a hinge structure therebetween extending along the bend line, the hinge structure having hinge ends that conform in shape with the end portions; and

wherein the hinge structure is dimensioned and configured for multiple bend and unbend cycles thereby providing a monolithic hinge connecting opposing panels of the sheet material on opposing sides of the bend line.

11. The sheet material of claim 10, wherein the sheet material is mild steel.

12. The sheet material of claim 10, wherein the sheared edge is a distance from the bend line that is at least 75% the thickness ("T") of the sheet material.

13. The sheet material of claim 10, wherein the displacement sheared edges comprise a substantially linear portion, and wherein adjacent sheared linear portions overlap one another for a distance that is at least approximately 3T.

14. The sheet material of claim 13, wherein the substantially linear portion extends between curved portions, and wherein adjacent sheared linear and curved portions overlap one another for a distance that is at least approximately 5T.

15. The sheet material of claim 10, further comprising displacement faces opposing the displacement sheared edges, the displacements configured to produce edge-to-face engagement between at least a portion of the sheared edges and a portion of the respective displacement faces while bending one of said opposing panels relative the other opposing panel about the bend line.

16. The sheet material of claim 10, the hinge structure is configured to bend and unbend at least 10 times.

17. The sheet material of claim 10, the hinge structure is configured to bend and unbend at least 50 times.

18. A three-dimensional structure comprising the sheet material claim 10, wherein one of said opposing panels forms a hinged access cover for access to a portion of the three-dimensional structure.

19. The three-dimensional structure of claim 18, wherein the structure is a box, and the hinged access cover is a lid providing access to an interior portion of the three-dimensional structure.

20. A substantially two-dimensional sheet material configured for bending along a bend line to form a three-dimensional structure having a hinge along the bend line, the sheet material comprising:

a sheet material substantially two-dimensional in a region in which a bend is to be made; and

a plurality of tongues positioned along opposing sides of the bend line, each tongue having a face directed toward the bend line and extending substantially parallel to the bend line, the tongue extending between end portions diverging away from the bend line; wherein adjacent faces overlap one another with respect to the bend line to form a hinge structure therebetween extending along the bend line, the hinge structure having hinge roots that conform in shape with the end portions; and

wherein the hinge structure is dimensioned and configured for multiple bend and unbend cycles thereby providing a monolithic hinge connecting opposing panels of the sheet material on opposing sides of the bend line.

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