US 20120159895A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2012/0159895 A1

Kawecki

(43) Pub. Date: Jun. 28, 2012

(54) SHEET METAL CONSTRUCTION TRUSS AND ITS METHOD OF CONTINUOUS AUTOMATED MANUFACTURE

(76) Inventor: **David Joseph Kawecki**, San Francisco, CA (US)

(21) Appl. No.: **13/078,910**

(22) Filed: **Apr. 1, 2011**

Related U.S. Application Data

(60) Provisional application No. 61/460,163, filed on Dec. 27, 2010.

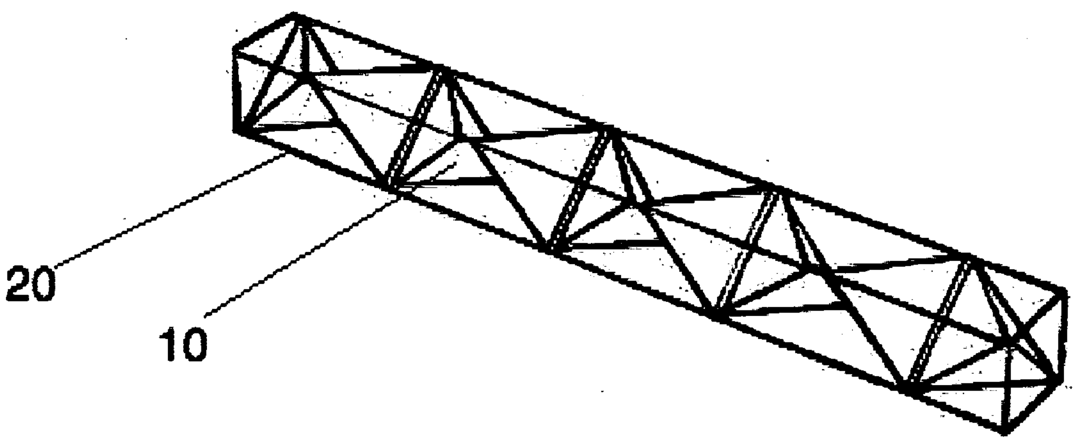
Publication Classification

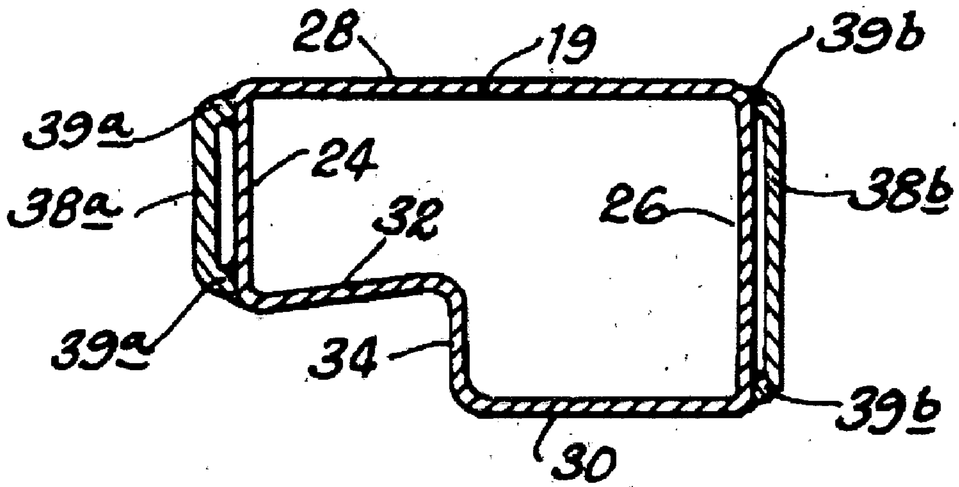
(51) **Int. Cl.**
E04C 3/04 (2006.01)
B23P 17/00 (2006.01)

(52) **U.S. Cl.** **52/834**; 29/897.35

(57) **ABSTRACT**

A linear construction truss comprising a hollow shell with a square cross section and a core composed of linked tetrahedra, and a method of manufacturing of said linear construction truss.





PRIOR ART

Fig. 1

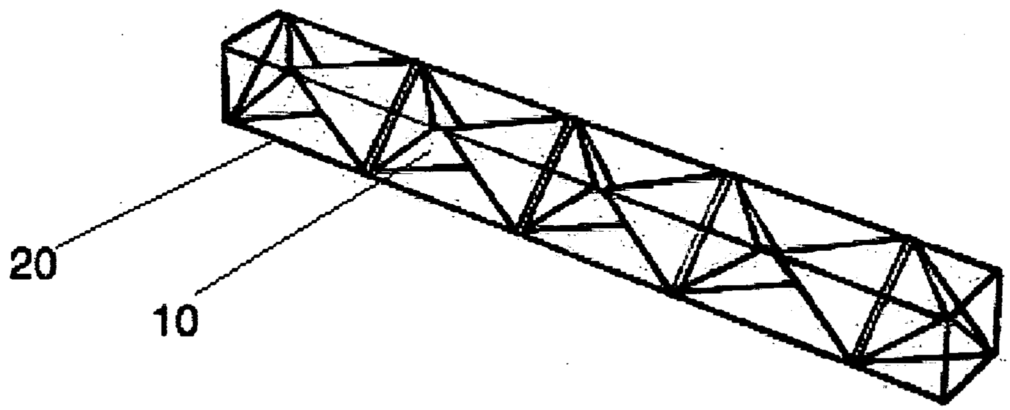


Fig. 2.

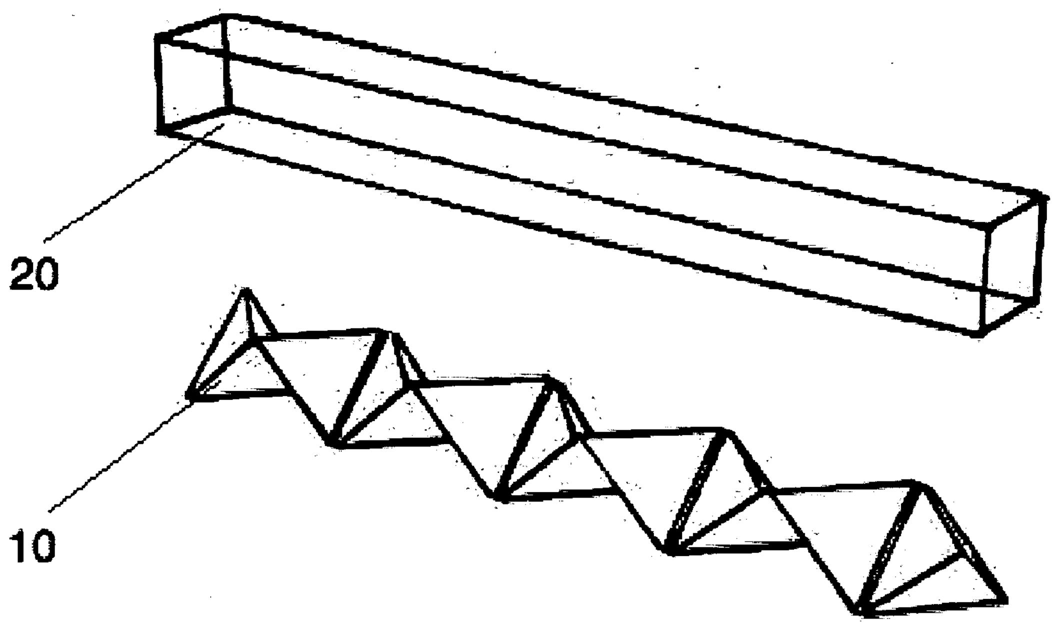


Fig. 3.

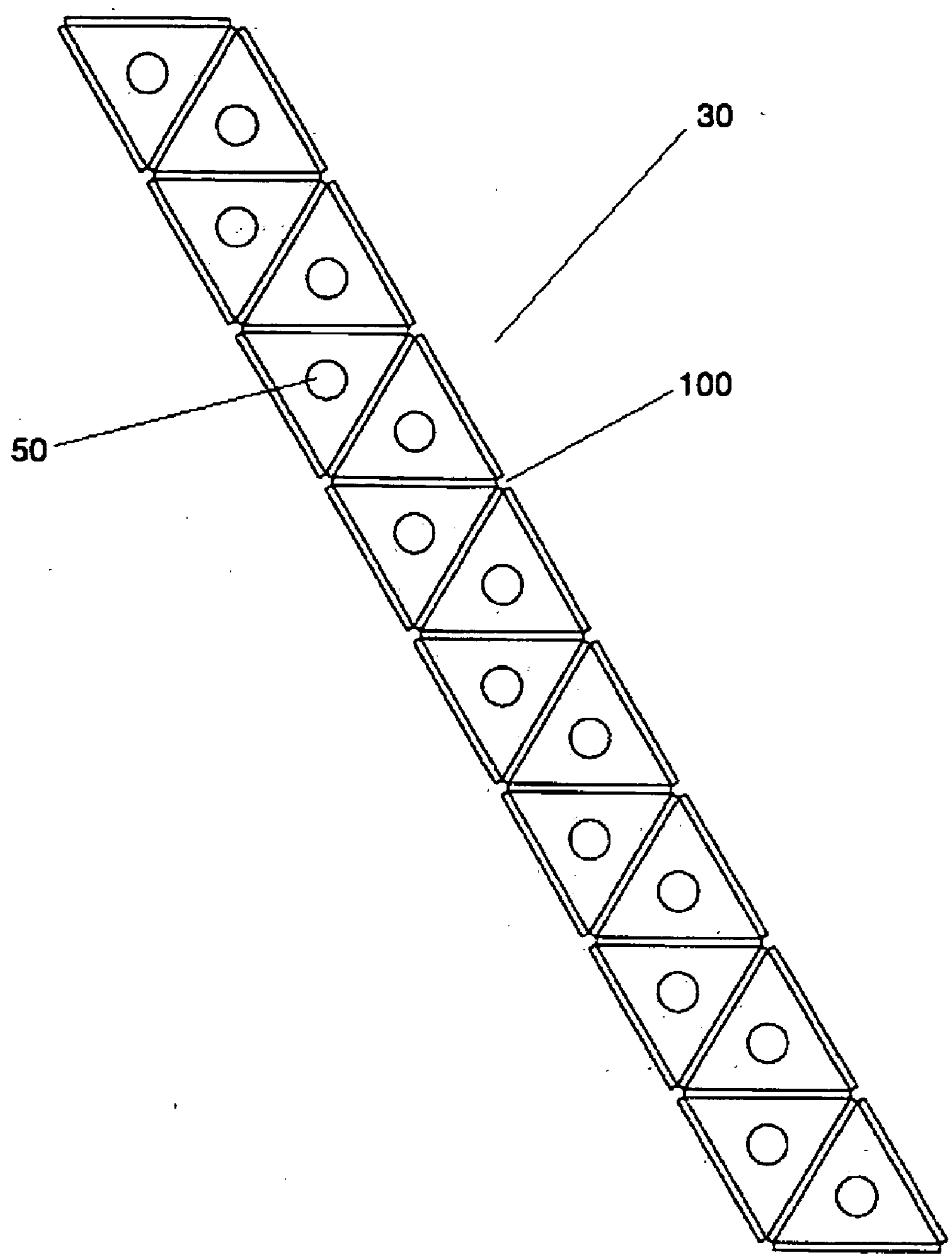


Fig. 4

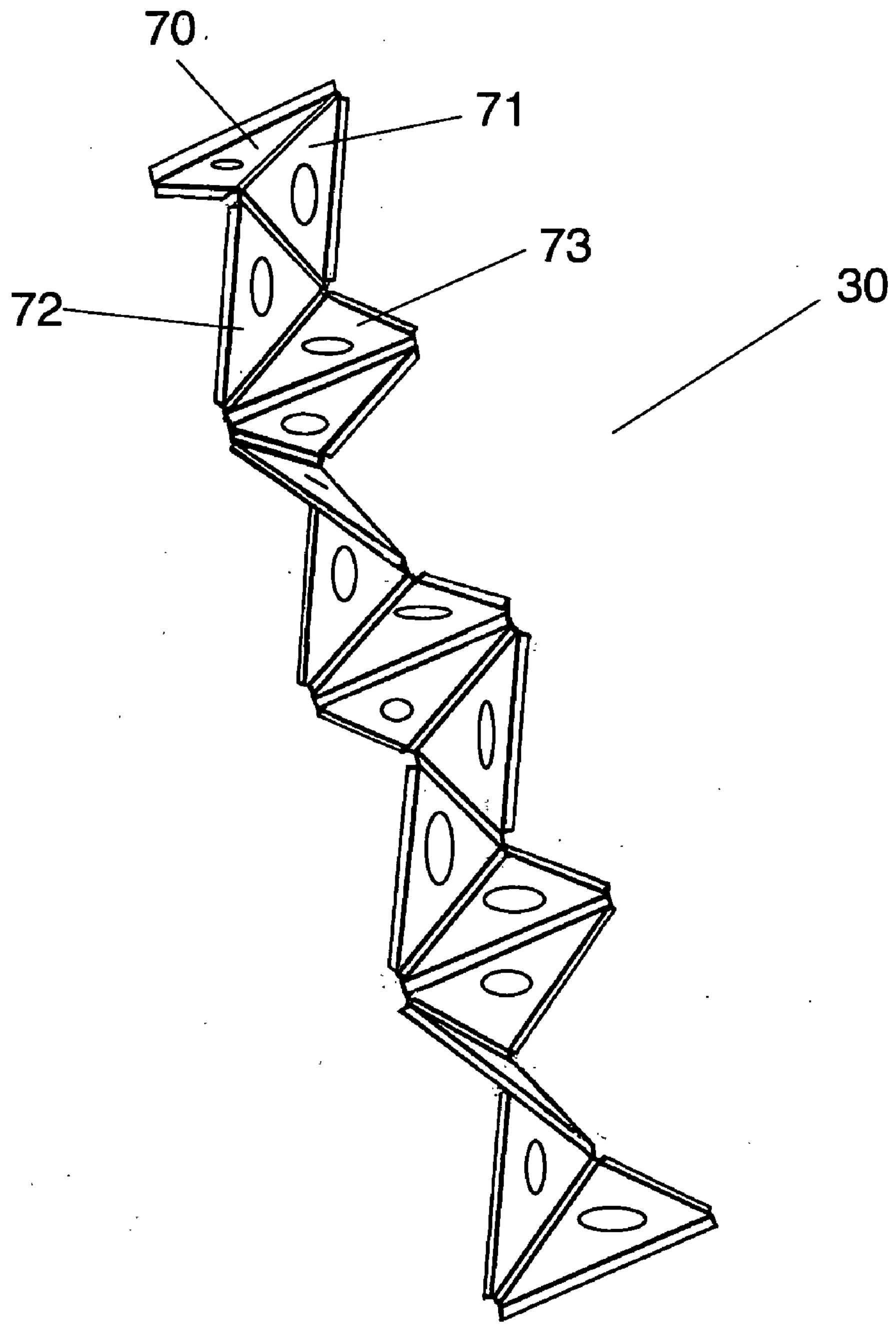


Fig. 5

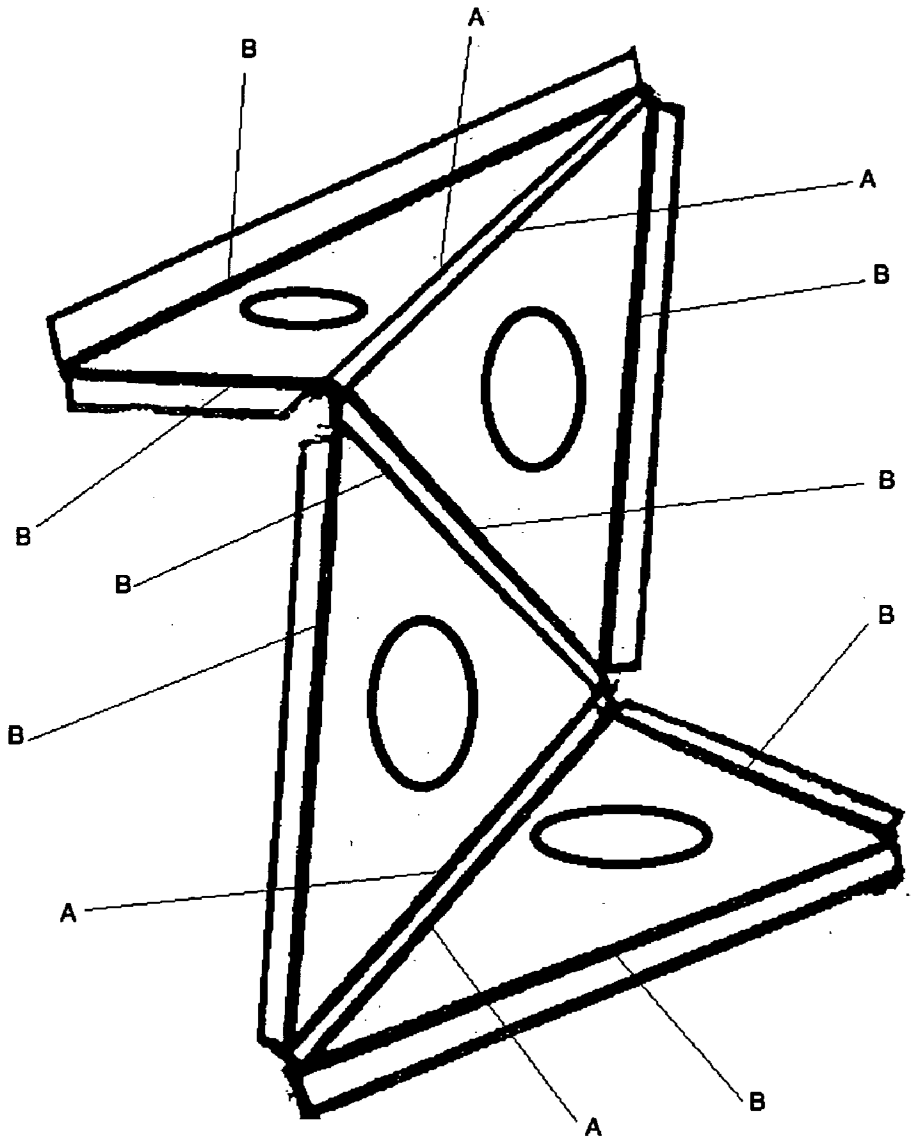


Fig. 6

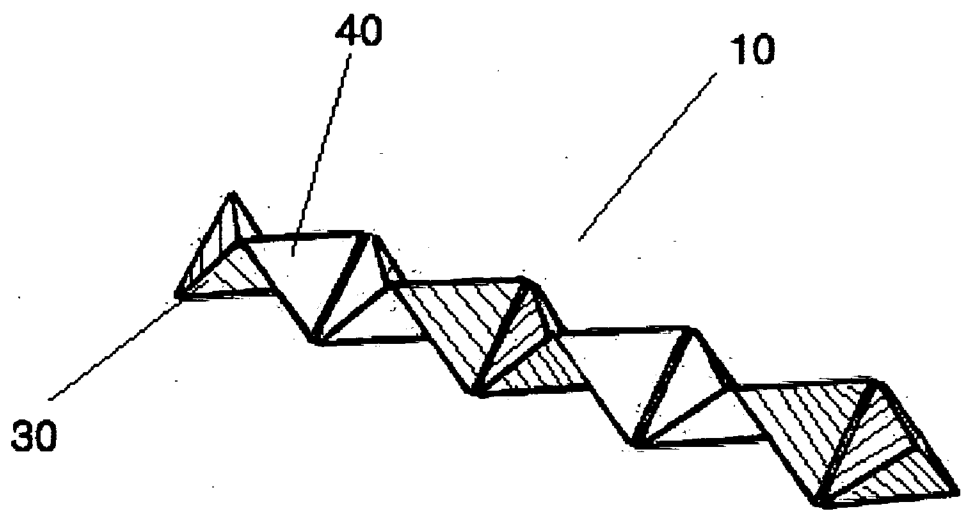
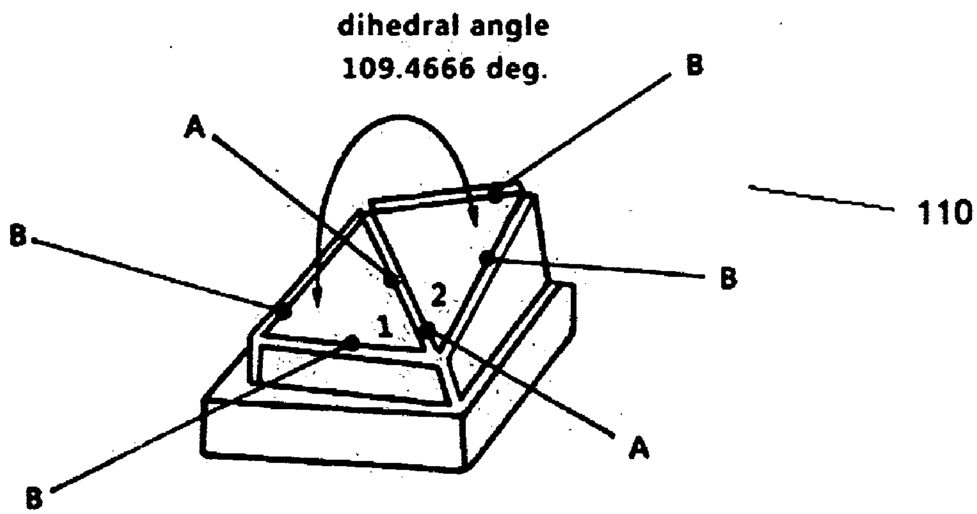


Fig. 7



A=144.7333 deg. B=234.7333 deg.

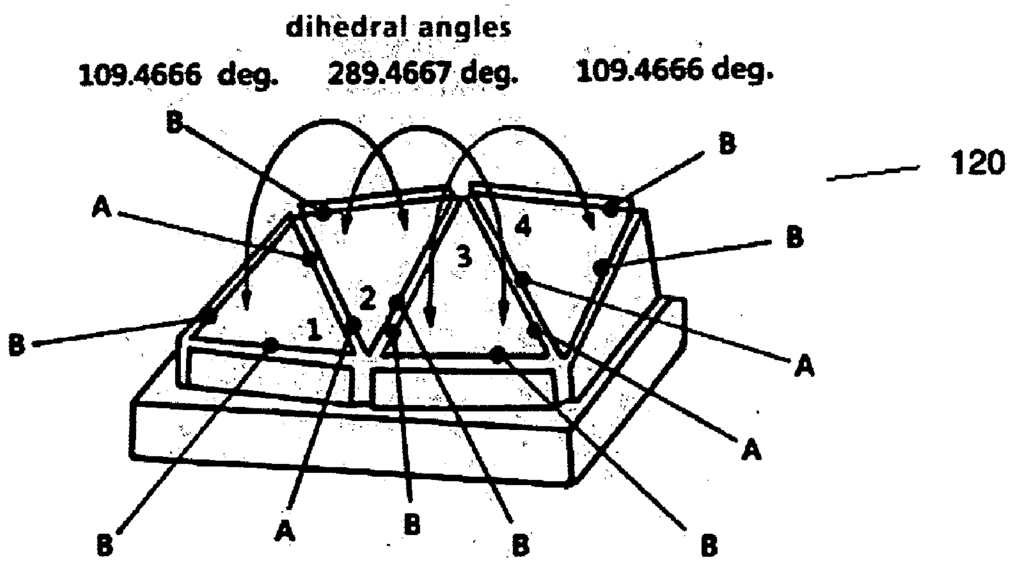


Fig. 8

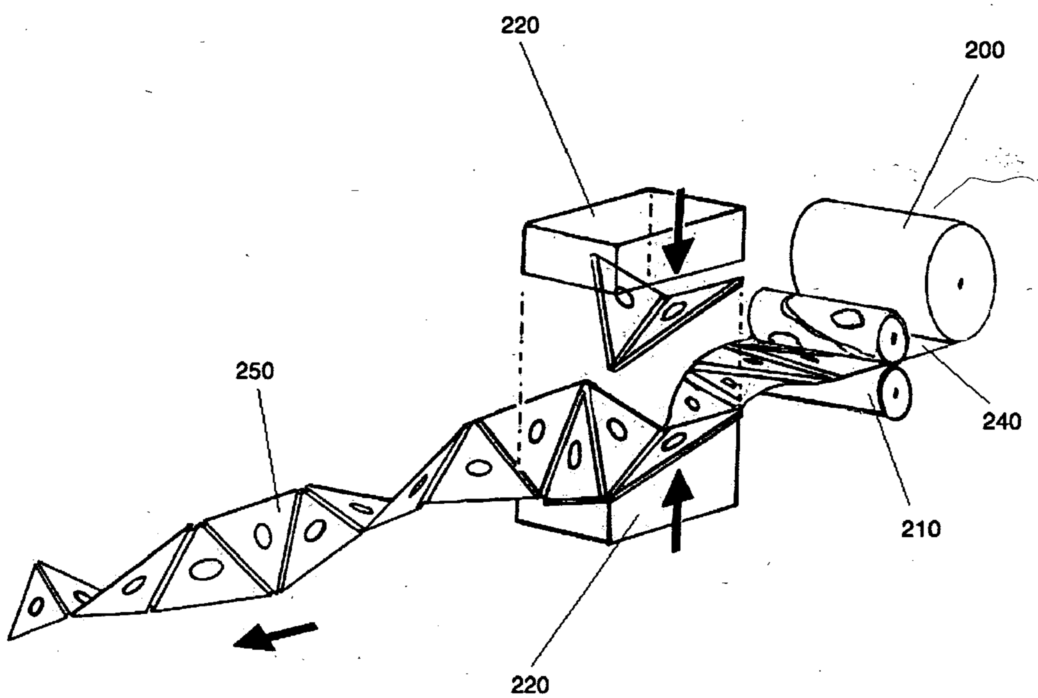


Fig. 9

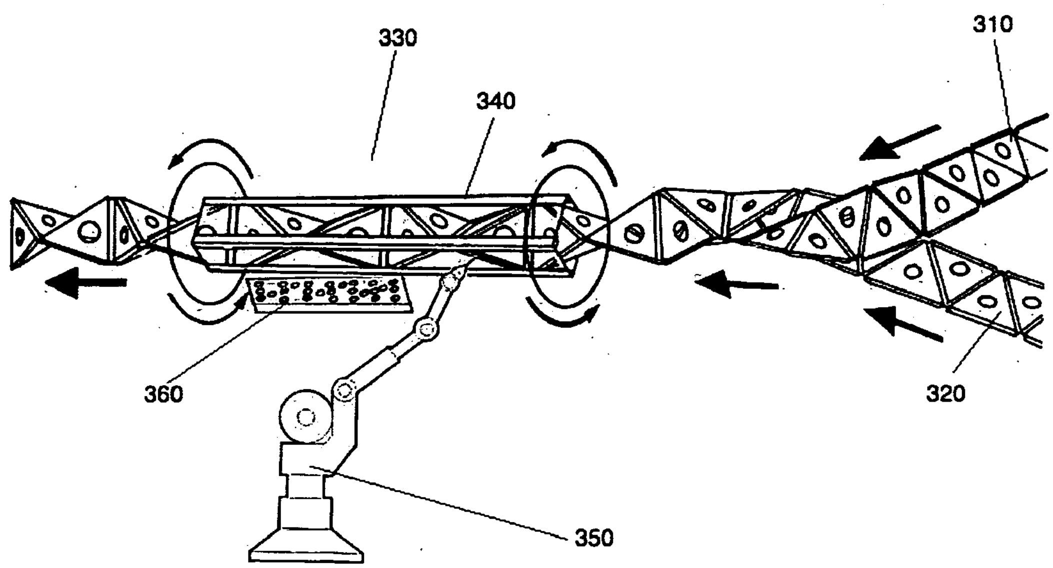


Fig. 10

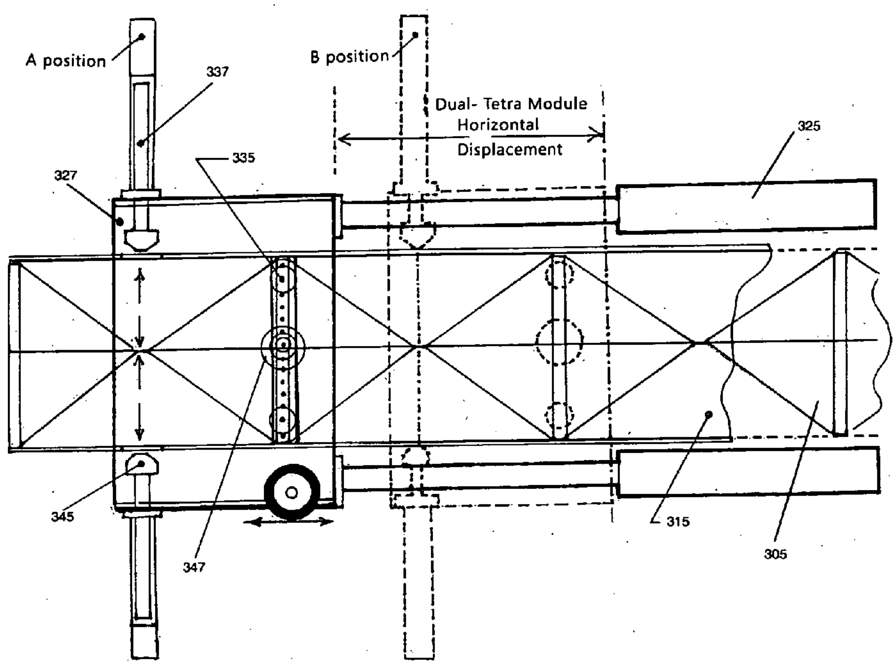

A position
B position
337
Dual- Tetra Module
Horizontal
Displacement
325
335
327
345
347
315
305

Fig. 11

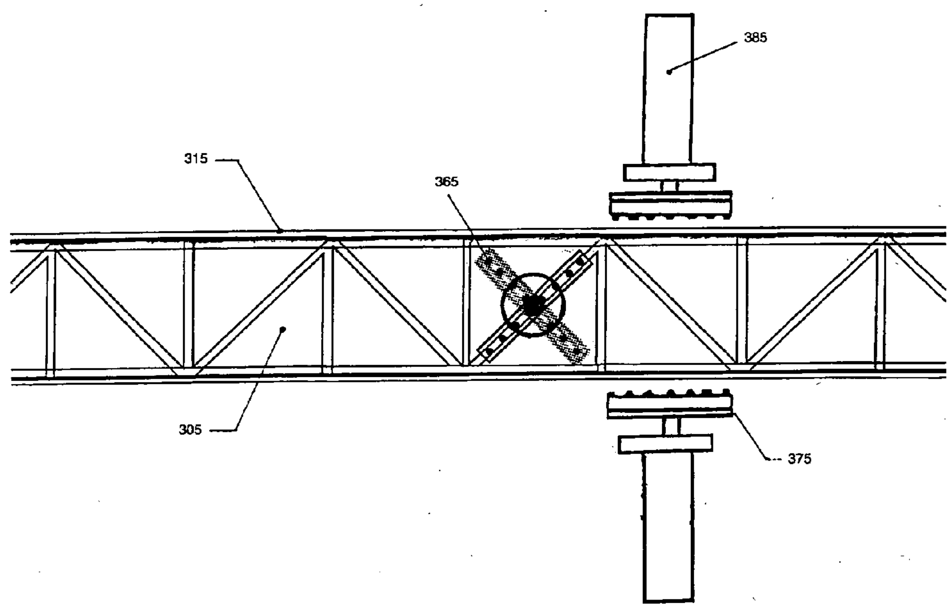


Fig. 12

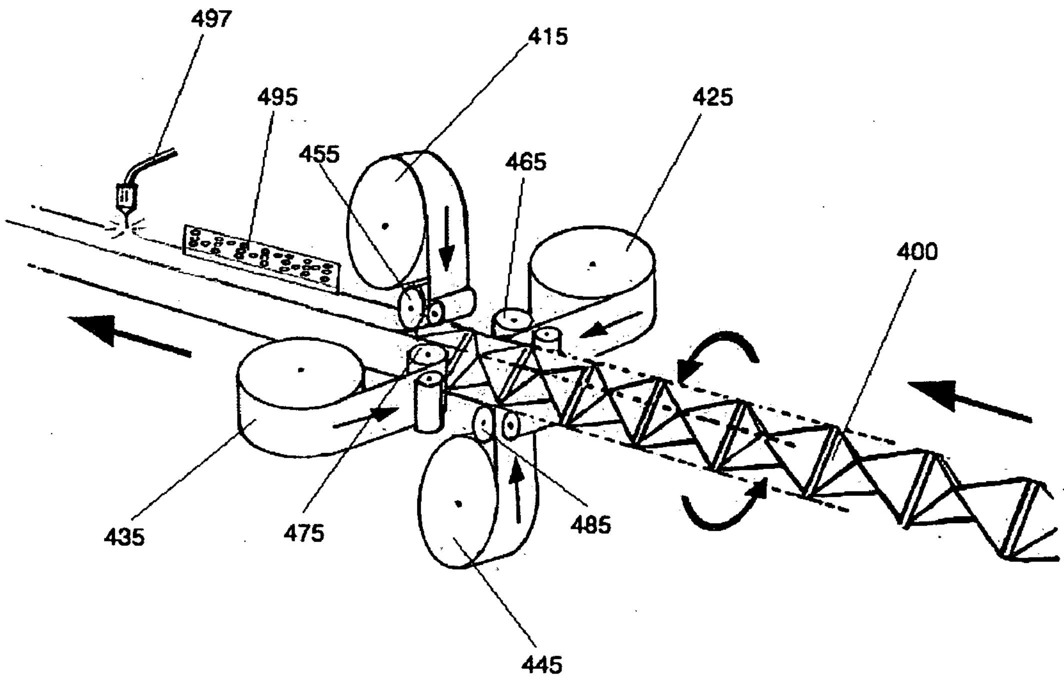


Fig. 13

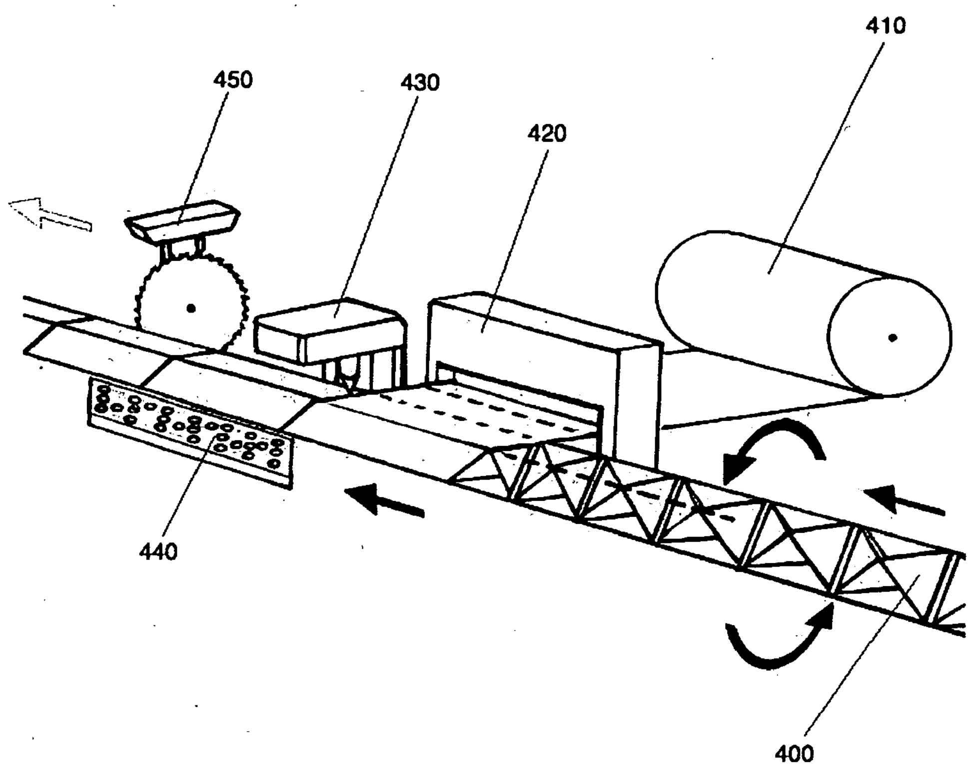


Fig. 14

SHEET METAL CONSTRUCTION TRUSS AND ITS METHOD OF CONTINUOUS AUTOMATED MANUFACTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Provisional Patent Application No. 61/460,163, filed Dec. 27, 2010, the contents of which is hereby incorporated by reference.

BACKGROUND

[0002] 1. Field of Invention

[0003] This invention relates to an improved design for a linear construction truss and a method of manufacturing said linear construction truss.

[0004] 2. Prior Art

[0005] There are many designs for linear members (beams and trusses) used in construction. Such linear members have to be resistant to shear stress and bending, since the loads on them are typically perpendicular to the axis of the linear member. The I-beam is one example of such a linear member. While the I-beam is an efficient design in that it concentrates the material where the largest linear stress is bound to occur, the manufacturing process for making I-beams involves hot rolling, which is very energy-intensive and environmentally damaging; furthermore, steel I-beams are relatively heavy.

[0006] Another possible type of design for a linear member is a hollow sheet metal box beam, such as the one described in U.S. Pat. No. 2,007,898 to Ragsdale. Ragsdale discloses a hollow sheet metal beam with a generally rectangular cross section. While such beams are lightweight and do not require energy-intensive hot rolling methods to construct, a beam with a hollow cross-section is not very strong, and susceptible to buckling.

[0007] Due to the advantages offered by a sheet metal construction over an I-beam or a lumber beam, many attempts have been made to reinforce a hollow sheet metal beam from the inside. One such design for a reinforced hollow sheet metal beam is disclosed in U.S. Pat. No. 3,783,498 to Moyer (shown in FIG. 1). Moyer discloses a beam with a hexagonal cross-section, made of sheet metal and welded. The beam is reinforced at two of its vertical sides with sheet metal strips welded to those two sides. These strips provide extra strength on the sides that bear the most stress. However, due to the fact that the horizontal sides are not reinforced and that there is no reinforcing elements on the interior of the beam, the resulting linear member is still not strong enough for some purposes.

[0008] Another method of reinforcing the interior of a hollow sheet metal beam is disclosed in U.S. Pat. No. 4,023,683 to Varga. Varga discloses reinforcing the interior of a hollow sheet metal beam with one or more planar webs. While that design is stronger than a simple hollow sheet metal beam, it is still not strong enough for some construction applications. One of the reasons for its relative lack of strength is that the planar webs are aligned with the axis of the beam, which increases the strain on these webs in normal operation.

SUMMARY OF THE INVENTION

[0009] The object of the present invention is to provide a linear member (a linear construction truss) that is stronger than prior art reinforced hollow beams, and to provide a method of manufacturing the linear construction truss that does not involve hot-rolled processes.

[0010] A linear member designed in accordance with the present invention is a linear construction truss comprising a hollow shell with a square cross-section and a reinforcing core of linked regular tetrahedra whose edge length is approximately equal to the inner diagonal of the cross-section of the hollow shell, the core being rigidly attached to the hollow shell. Such a design offers many advantages, one of them being that rather than providing a single planar web to reinforce a hollow beam, the design provides many planar webs (i.e. the faces of the tetrahedra), which are disposed at varying oblique angles relative to the axis of the linear construction truss. This reduces the linear strain on the reinforcing material and renders the linear member stronger. Furthermore, the inter-tetrahedral webs reinforce alternate diagonals of the hollow shell, which also improves its strength and resistance to buckling.

[0011] The intra-tetrahedral edges, when joined to the shell, comprise two single layer struts, three double layer struts, and two triple layer struts per linear tetrahedral module. The double and triple layer struts join to form two double layer and two triple layer helices coiling in opposite directions along the length of the truss. These mutually reinforcing structures arrange in an X-form triangulation of the diametric shell corners per tetrahedral module, normal to the rectangular shell's axis. These bi-directional coiling elements impart a cable-like resilience to the structure, and render it stronger than prior art reinforced hollow beams.

[0012] In a preferred embodiment, both the hollow shell and the reinforcing core are made of sheet metal, though other materials may also be used. Due to its square cross-section, such a linear construction truss can be used in place of a lumber beam or an I-beam in construction applications. Furthermore, a sheet metal linear construction truss in accordance with the present invention is more lightweight than either a lumber beam or a steel I-beam and requires only cold-rolled processes to manufacture. Thus, it offers the advantages of a sheet metal design, while also offering improved strength over prior art reinforced sheet metal designs.

[0013] In a preferred embodiment, the intra-tetrahedral edges that attach to the hollow shell are chamfered to facilitate attachment to the hollow shell. The inter-tetrahedral edges are not chamfered.

[0014] Another aspect of the present invention is a method of continuous automated manufacture of a linear construction truss as described above. Both the reinforcing core and the hollow shell can be manufactured from sheet metal strips using simple folding and stamping processes.

[0015] In accordance with the manufacturing method of the present invention, two identical sheet metal strips are cut and bent in such a way as to result in a plurality of triangular faces with specified angles between the triangular faces. In a preferred embodiment of the invention, there are chamfers between the triangular faces. The two strips are then intertwined together to form a reinforcing core comprising a plurality of linked regular tetrahedra, and rigidly attached. A sheet metal shell with a square cross-section is then formed around the reinforcing core and rigidly attached to it.

DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** shows a prior art design of a reinforced hollow sheet metal beam.

[0017] FIG. **2** shows a linear construction truss of the present invention.

[0018] FIG. **3** shows a separate view of the hollow shell and a separate view of the reinforcing core.

[0019] FIG. **4** shows a view of one of the two sheet metal strips used to form the reinforcing core.

[0020] FIG. **5** shows a view of one of the two sheet metal strips used to form the reinforcing core after it is folded in accordance with the present invention.

[0021] FIG. **6** shows a view of a chamfer between two of the triangular faces of the folded sheet metal strip.

[0022] FIG. **7** shows a view of the reinforcing core.

[0023] FIG. **8** shows two possible designs for a die used to bend the sheet metal strips that comprise the reinforcing core.

[0024] FIG. **9** shows an embodiment of a die forming station.

[0025] FIG. **10** shows a view of an embodiment of a core assembly station.

[0026] FIG. **11** shows a side view of a web welder module of another embodiment of a core assembly station.

[0027] FIG. **12** shows a side view of a chamfer welder module of the same embodiment of a core assembly station.

[0028] FIG. **13** shows an embodiment of a shell application station.

[0029] FIG. **14** shows an alternate embodiment of a shell application station.

DETAILED DESCRIPTION OF THE INVENTION

[0030] FIGS. **2** and **3** show the main component parts of the linear construction truss of the present invention—the reinforcing core **10** and the shell **20**. FIG. **2** is a view of the assembled linear construction truss with a transparent view of the hollow shell. FIG. **3** shows a separate view of the reinforcing core and a separate view of the hollow shell. As can be seen in FIG. **2**, the reinforcing core **10** comprises a plurality of linked regular tetrahedra, situated inside a hollow shell **20** with a square cross-section such that the linked edges of the tetrahedra are approximately equal to the inner diagonal of the hollow shell. Each tetrahedron, except for the ones located on each end of the truss, is, rigidly linked to its two neighboring tetrahedra along two of its edges, and rigidly linked to the inner surface of the hollow shell along its four other edges. This strengthens the structure by providing numerous planar reinforcing surfaces at oblique angles to the load. In a preferred embodiment, both the hollow shell and the reinforcing core are die-formed from continuous sheet metal strips by automated cutting and folding machines that process rolls of sheet metal; it is preferable, though not required, that the sheet metal strips that form the reinforcing core be thinner than the sheet metal strips that form the hollow shell.

[0031] FIG. **4** shows one of the two identical sheet metal strips **30** used to form the reinforcing core. In a preferred embodiment, the strip is die-cut with cutouts **100** to facilitate folding and chamfering, and cut with perforations **50** to reduce its weight.

[0032] FIG. **5** shows a view of sheet metal strip **30** after it is folded. The strip **30** is folded in such a way that the dihedral angles between successive triangular faces alternate between 109.4667 degrees and 289.4667 degrees throughout the length of the strip. For example, the dihedral angle between triangular face **70** and triangular face **71** is 109.4667 degrees; the dihedral angle between triangular face **71** and triangular face **72** is 289.4667 degrees; the dihedral angle between triangular face **72** and triangular face **73** is 109.4667 degrees; and so on. This results in a helical shape that can then be intertwined with another identical shape to form a plurality of linked tetrahedra.

[0033] In the preferred embodiment, there are chamfers between the triangular faces, as shown in FIG. **6**, which is a magnified view of a section of sheet metal strip **30**. The bending angles at the edges labeled "A" are approximately 144.7333 degrees; the bending angles at the edges labeled "B" are approximately 234.7333 degrees. This pattern repeats throughout the length of the strip. The chamfers are intended to facilitate welding, both for welding the two strips together to form the tetrahedra and for welding the tetrahedra to the hollow shell.

[0034] FIG. **7** shows the two sheet metal strips **30** and **40** joined together to form the reinforcing core **10**. Sheet metal strip **30** is shaded while sheet metal strip **40** is left unshaded. As can be seen in the figure, each tetrahedral unit derives its parts from both of the two core strips. From each strip, each tetrahedral unit derives two of its four triangular faces, two of its four chamfered edges, and one of its two inter-tetrahedral web layers. The successive inter-tetrahedral web layers are at right angles to each other and normal to the core axis. The core is thus composed of the two helices of equilateral triangles and strips that will be precisely coiled together and, in a preferred embodiment, joined with spot or linear welds.

[0035] The hollow shell **20** encloses, triangulates, and is welded to, the core **10**, as is shown in FIG. **2**. It is a linear tube with a square cross-section. Depending on the machinery deployed, it can comprise one, two, or four separate sheet metal strips. These are die-cut and folded for corners and edge joining, then welded at the seam or seams and welded to the core.

[0036] The linear construction truss may be manufactured by using cold-rolled processes such as stamping or bending. FIG. **8** shows two possible designs for a die used to form the folded sheet metal strips that comprise the reinforcing core. Die **110** can achieve the folding of two facets per die strike; die **120** can achieve the folding of four facets per die strike. Alternate numbers of facets may also be used. The chamfer angles are identified on the drawing. For die **110**, the dihedral angle between faces **1** and **2** is 109.4666 degrees; the chamfer angles are 144.7333 degrees on the edges marked A and 234.7333 degrees on the edges marked B. For die **120**, the dihedral angle between faces **1** and **2** is 109.4666 degrees, as is the dihedral angle between faces **3** and **4**. The dihedral angle between faces **2** and **3** is 289.4667 degrees. The chamfer angles are 144.7333 degrees on the edges marked A and 234.7333 degrees on the edges marked B.

[0037] FIG. **9** shows one possible embodiment of a die forming station that continuously forms a folded sheet metal strip used to form the tetrahedral reinforcing core. A sheet metal strip **240** is continuously fed from a roll **200** into a rotary die cutter **210**, which cuts it with cutouts to facilitate folding and chamfering and perforations to reduce its weight. After it is cut, the strip is folded in a die **220**. The folded strip **250** is then ready to be welded together with a second identical strip to form the tetrahedral core.

[0038] FIG. **10** shows an overview of one possible embodiment of a core assembly station that assembles the two folded strips into a tetrahedral reinforcing core. Two folded strips **310** and **320** are continuously fed into a rotating assembly fixture **330**, which rotates around the axis of the reinforcing core. The rotating assembly fixture **330** holds the two strips **310** and **320** in correct angular position for welding by means of registration chute **340**. Registration chute **340** is an axially revolving rectangular chute that moves the core forward in steps to the next operation. The entire assembly moves forward in steps through the revolving fixture; at each stopping point, automatic welding, performed by a robot **350** or a weld array **360**, joins the various weld points of the core, starting with the inter-tetrahedral web and following with the tetrahedral chamfer-flanges. The reinforcing core is then ready to be assembled with the hollow shell at the shell application station.

[0039] Another embodiment of a core assembly station is detailed in FIGS. **11** and **12**, and comprises two independent modules. One module—the web welder module—welds the intertetrahedral webs of the core, and moves the core forward in steps to the next operation. The other module—the chamfer welder module—welds the chamfered edges of the tetrahedra.

[0040] FIG. **11** shows a side view of the web welder module. Truss core **305** enters the assembly module from the right side of the drawing, and is held in the registration chute **315**. The main linear actuator **325** moves the weld frame **327**, which contains the vertical and horizontal weld arrays into position for the welding of the intertetrahedral webs. Weld array **335** is vertical and is used to weld the vertical intertetrahedral webs; weld array **345** is horizontal and is used to weld the horizontal intertetrahedral webs. Vertical linear actuators **337** move the horizontal weld arrays **345** into position for welding; horizontal linear actuators **347** move the vertical weld arrays **335** into position for welding. The main linear actuator **325** then moves the weld arrays in the direction parallel to the truss core axis and enables them to move the truss core through the module; the range of its displacement is labeled as "Dual-Tetra Module Horizontal Displacement" in FIG. **11**. Two positions of the weld arrays—"A position" and "B position"—are shown in FIG. **11**.

[0041] FIG. **12** shows a side view of the chamfer welder module. This module welds the intratetrahedral edges after the intertetrahedral webs have been welded. Truss core **305** enters this module from the right side of the drawing, and is held in the registration chute **315**. The vertical diagonal weld arrays **365** are used to weld the intratetrahedral edges that are vertical; a corresponding set of horizontal diagonal weld arrays **375** are used to weld the intratetrahedral edges that are horizontal. Vertical linear actuators **385** and horizontal linear actuators (not shown) bring the weld arrays into position.

[0042] One embodiment of the shell application station is shown in FIG. **13**. The finished core **400** rotates around its axis due to the action of the core assembly station shown in FIGS. **10-12**. Four rolls of sheet metal, **415**, **425**, **435**, and **445**, rotate along with the core. Rotary dies **455**, **465**, **475**, and **485** apply the four strips of sheet metal to the sides of the core to form the shell; spot weld arrays then weld the strips of sheet metal to the core and corner welders weld the strips of sheet metal together. For clarity, FIG. **13** shows only one spot weld array **495** and one corner welder **497**, out of the four required spot weld arrays and four corner welders. This embodiment is not the preferred embodiment of the shell application station because it necessitates that the entire apparatus revolve around the shell axis, which is complex and expensive.

[0043] The preferred embodiment of the shell application station is shown in FIG. **14**. The finished core **400** is fed into the shell application station; a roll of sheet metal **410** is fed into a diagonal corner fold die **420** and is applied to the core **400** at an angle that enables it to be wrapped around the core **400** in a spiral pattern. This method of applying the shell is more efficient because the whole apparatus can remain stationary and only the core **400** rotates. A seam welder **430** welds the successive coils of the spiral together; a spot weld array **440** welds the core assembly to the shell. A cut-off saw **450** cuts off finished lengths of the linear construction truss in modular lengths at the tetrahedral web.

1. A linear construction truss, comprising:
- a hollow shell with a square cross-section;
- a core located inside the hollow shell, comprising a plurality of tetrahedra rigidly connected together at their edges, the edge length of each tetrahedron being approximately equal to the inside diagonal of the cross-section of the hollow shell.

2. The linear construction truss of claim **1**, where the core is rigidly connected to the hollow shell.

3. The linear construction truss of claim **1**, where the tetrahedra are hollow.

4. The linear construction truss of claim **1**, where the tetrahedra are chamfered in such a way that the chamfered surfaces can be rigidly connected to the sides of the hollow shell.

5. The linear construction truss of claim **3**, where at least one face of at least one tetrahedron has at least one perforation.

6. The linear construction truss of claim **1**, where the hollow shell and the core are made of sheet metal.

7. A method of manufacturing a linear construction truss, comprising:
- bending a first sheet metal strip in such a way as to result in a plurality of equilateral triangular faces where the altitude of each triangular face approximately equals the width of the sheet metal strip, such that:
  - the angle between a first triangular face and a second triangular face is approximately 109.4667 degrees;
  - the angle between the second triangular face and a third triangular face is approximately 289.4667 degrees;
  - the angle between the third triangular face and a fourth triangular face is approximately 109.4667 degrees;
  - the angles between neighboring faces continue to alternate between approximately 109.4667 degrees and approximately 289.4667 degrees throughout the length of the first sheet metal strip;
- bending a second sheet metal strip identically to the first sheet metal strip;
- rigidly connecting the first sheet metal strip and the second sheet metal strip in such a way as to result in a core of linked tetrahedra;
- forming a hollow shell with a square cross-section such that the length of the inner diagonal of the cross-section is approximately equal to the edge length of the tetrahedra;
- rigidly connecting the core to the hollow shell.

8. The method of claim **7**, where the bending step comprises chamfering the area between the triangular faces in such a way that the chamfer surfaces can be rigidly connected to one of the sides of the hollow shell.

9. The method of claim **7**, where the forming step comprises winding a strip of sheet metal around the core in a spiral pattern in order to form the hollow shell.

10. The method of claim **7**, where the forming step comprises winding a plurality of strips of sheet metal around the core in a spiral pattern in order to form the hollow shell.

11. The method of claim **7**, where the forming step comprises rigidly connecting four sheet metal sides on the outside of the tetrahedral core in order to form the sides of the hollow shell.

12. The method of claim **7**, where prior to the bending step, one or both of the first sheet metal strip and the second sheet metal strip are cut in such a way that the perforations do not impinge on the edges of the tetrahedra.

* * * * *