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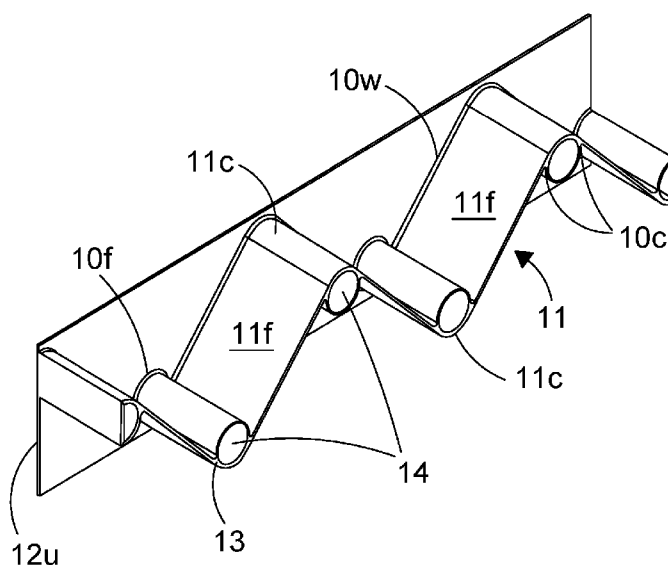


FIG. 1

(57) Abstract: A structural support member is disclosed. It has at least two longitudinally extending flanges spaced apart from one another by an assembly comprising a web and at least one reinforcing member. The web comprises at least one wave-shaped web portion arranged perpendicularly to the flanges, and at least one apex of the at least one wave-shaped web portion comprises at least one reinforcing member. The structural support member is typically formed as a beam.



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SUPPORT MEMBER

This invention relates to a support member, particularly a structural support member with applications in fields such as civil engineering, offshore oil and gas, aerospace, marine, and mechanical engineering structures and equipment. More particularly, the invention relates to a structural support member comprising a wave-shaped web connecting top and bottom flanges.

BACKGROUND TO THE INVENTION

Currently, conventional I-beams are widely used as structural support members to provide safe spans, and resist transverse loading and/or safely support vertical loads across such spans. An I-beam comprises a flat vertical web of a specified thickness. Flat horizontal plates of a specified thickness are rigidly connected to the top and bottom of the web, with both the top and bottom plates being referred to as the I-beam flanges. Hence, the web and flanges have the shape of a capital I (or H on its side). As an I-beam resists vertical loading across its span between various point and patch loading loci, the downward sagging part of the beam bends with compression in the upper flange and tension in the lower flange (and vice versa for upward beam hogging sections). The ability of an I-beam to resist these bending-induced forces depends critically on the vertical distance between the two flanges, where greater vertical beam depth between the two flanges reduces the flange compression and tension forces for the same bending moment (force by distance) resistance.

For more than a century I-Beams have been used extensively in structural steelwork, civil engineering and marine structures and mechanical equipment, to safely resist applied loads transferred to the span of the beam between its supports. In more recent times, successful efforts have been made to improve the structural robustness of I-beams by changing the shape of the web of the beam. For example, a beam with a corrugated sinusoidal wave-shaped web has been manufactured and successfully used in steelwork construction today. The

sinusoidally corrugated web shape increases the beam's resistance to web buckling allowing for a greater vertical distance between the horizontal beam flanges.

5 Examples of such beams are shown in US6520707, US8468774, US4734146, US4197978, US2125692, KR101086293B, KR100714662B and CN101761184A, which are useful for understanding the present invention. There is also a body of academic research which has been carried out on the incorporation of sinusoidal, triangular and trapezoidal shaped webs into structural beams.

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SUMMARY OF THE INVENTION

According to the invention there is provided a structural support member comprising at least two longitudinally extending flanges spaced apart from one another by an assembly comprising a web and at least one reinforcing member, wherein the web comprises at least one wave-shaped web portion arranged perpendicularly to the flanges, and wherein at least one apex of the at least one wave-shaped web portion comprises at least one reinforcing member.

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Optionally the structural support member is a beam. Optionally the reinforcing member is substantially tubular. Optionally the reinforcing member is at least partially hollow, optionally centrally hollow. Optionally the or each reinforcing member is hollow along its length. Optionally the reinforcing member is a cylinder, optionally circular in cross-section. Alternatively, the reinforcing member may be square, rectangular, triangular, oval, or any other shape in cross-section.

25

Optionally the reinforcing members are positioned on the inner sides of the apexes of the web (where apex refers to any turning point of the wave forming the web and thereby includes areas that may, to the observer, appear as troughs/nadirs), closer to the central axis of the beam and/or flanges. Optionally the or each apex encapsulates the reinforcing member. The addition of reinforcing members at apexes of the web offers the advantage of significantly increased resistance to beam lateral-torsional buckling, which in turn permits a reduction in the thickness of the web and flange walls, thereby reducing the

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weight of the beam as a whole. Typically, the beam may weigh around 40% less than an I-beam manufactured from the same material and having the same bending moment resistance capability. Furthermore, as the apexes of the web and the reinforcing members deviate from one side of the beam to the other along the length of the web, the resistance of the beam against lateral and torsional buckling under extreme vertical loading is also increased.

Optionally the shape of the wave in the web is substantially symmetrical, for example sinusoidal. Alternatively, it may be another type of wave such as a square wave, a triangular wave, or similar. Optionally the distance between two apexes of the wave forming the web where the apexes are disposed on opposing sides of the flange (i.e., where the apexes are a “peak” and a “trough”), is between 50-100% of the width of the flanges, for example between 80-95% of the width of the flanges. Optionally the section of the web between each apex is substantially flat or linear. The shape and extent of the wave-shaped web provides increased resistance to beam shear loading and web buckling in comparison to the flat web of an I-beam. This increases the beam load capacity and structural robustness while reducing web and flange thicknesses, thereby further reducing the overall material weight of the beam.

Optionally a portion of the web at one or both ends may extend along, or parallel with, the longitudinal axis of the beam. This offers the advantage that the beam can be retrofitted into existing connections configured for conventional beams such as I-beams.

Optionally at the contact sites between the or each reinforcing member and the web, the joins between the reinforcing member and the web creates a portion of the assembly with a greater cross-sectional thickness than the web alone. This increase in thickness provides further rigidity and strength to the beam.

Optionally the thickness of the web may be varied as required. Optionally the dimensions of the reinforcing member, for example the cross-sectional area, the diameter, and so forth can be varied. Optionally the angle of wave deviation and

optionally the dimensions of the inner section of the wave into which the reinforcing member is fixed can also be varied, for example, the diameter of the inner curve of the wave may change.

- 5 The configuration of the combination of the wave-shaped web and the, or each, reinforcing member has a synergistic effect where the web provides vertical support to the reinforcing members, and the reinforcing members provide lateral and torsional support to the web.
- 10 Optionally the web may comprise cut-out portions to reduce the weight of the beam yet further. For example, the web may comprise a series of circular apertures where material has been removed from the web. Optionally the apertures may be substantially circular holes, optionally arranged in a “gun barrel” configuration, having a central hole surrounded by a symmetrical
- 15 concentric circular arrangement of holes. Other shapes of cut-out portions and other arrangements of apertures and/or cut outs may be used. Optionally services such as power or communications conduits may be routed through the cut-out portions.
- 20 Optionally the beam may be made of steel. Optionally the beam may be made of aluminium or another metal that is sufficiently robust to meet the requirements of the location of use of the beam. Alternatively, and according to the intended use of the beam, the beam may be made of plastic, composites, or any other suitable structural material. Optionally, the beam may be made of a combination of
- 25 suitable materials.

Optionally the components of the beam, i.e. the flanges, web, and reinforcing members, can be formed as one integral piece. For example, the beam may be made of steel and may be formed by milling or casting.

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Optionally a beam may be formed of several integrally-formed pieces connected together to extend the span of the beam. Optionally the connections between the pieces form a continuous, strong structural connection between all of the

components of the beam, such as the web, flanges, and reinforcing members, such that the beam acts as one structure.

Optionally the components of the beam may be formed separately and fixed together. For example, the wave-shaped web may be formed as one component and the reinforcing members may then be fixed (for example welded or spot welded) to the apexes of the web. Optionally the wave-shaped web may be welded, optionally spot welded, at a first side to a flange either before or after the reinforcing members are affixed to the web before the second flange is then affixed to the second side of the web, completing the beam, or completing a section of the beam. Optionally the reinforcing members may be affixed to a flange first, and the wave-shaped web may then be affixed to the flange and the reinforcing members.

Optionally the web may be fabricated from multiple modular sections (for example, the web may be fabricated in modular form from repeated modular components), each optionally comprising one whole apex and two half apexes. This can be a useful way of manufacturing webs from material of greater than 5mm thickness, for example. For example, several approximately V-shaped curved sections, where the reinforcing members are cylinders, may be fabricated, where each end of the section is a partial circumference of a cylinder and approximately half of the length of an apex. These modular sections may be welded or otherwise affixed together to form the required length of web for the required length of beam. Optionally at the ends of the modular sections, where the sections are joined together, three weld areas may be used: a weld on either side of the reinforcing member to attach the reinforcing member to the web, and another weld joining two modular sections together. Optionally, on the continuous section of the modular sections, two weld areas positioned on either side of each reinforcing member may be used to fix the reinforcing member to the web.

Optionally at the locus where the web meets the reinforcing member there may be a space, for example, where the reinforcing member is a cylinder, there may be a substantially triangular space formed between the curved side of the

cylinder and the flat portion of the web, just before the web begins to curve around the cylinder. Optionally the space formed between the reinforcing member and the web may be chamfered to create weld slots. Optionally an additionally thickened section of wall can be created on the inner side of the web
5 between the reinforcing member and the web by the or each weld slot, providing further strength to the assembly.

Optionally larger modular sections of the web may be fabricated, for example zigzag shaped modular sections comprising more than one complete turn (i.e. a
10 continuous section including more than one complete apex of the web). This can be a useful way of manufacturing webs of , for example, less than 5mm. Optionally the web is initially manufactured as a flat section and bent into the desired shape, e.g. the zigzag shaped modular section. The larger modular sections are affixed to the flanges to create the beam as described above.

15 Optionally one or more beams may be incorporated into modular interlocking sections, for example, interlocking deck floor box sections. Optionally the sections may have the same or a similar area as shipping containers for convenient transportation. Optionally the sections may be supplied and fitted in
20 modular sections to create the desired size of e.g. deck floor sections. Optionally the sections may comprise the beam according to the invention alternating with a conventional beam such as an I-beam or H-beam to form the overall modular section.

25 The reduction in weight offered by the beam permits large platforms, optionally formed from such interlocking deck floor box sections, to be affixed to ageing oil and gas production assets, offering an economically viable solution to extending the lifetime of such assets and continuing to produce from fields that may otherwise have been abandoned. For example, the addition of two 16m x 16m
30 platforms comprising beams in accordance with the invention would provide a greater physical laydown area than a standard supply vessel at a lower cost, substantially increasing the physical laydown area of existing assets. This could be achieved by, for example, making use of the free overhanging deck space

and attaching large platforms formed either entirely or partially of beams in accordance with the invention to the sides of the existing deck.

Alternatively, permanent interlocking deck floor sections could be integrated into existing assets or new build platforms.

The lightweight nature of the beam also offers advantages in other areas of the offshore (and onshore) oil and gas industry such as decommissioning, TAR applications, well intervention, plugging and abandonment, and fracking operations. The beam could be used for repairs on ageing assets with integrity issues; for undertaking essential platform repairs where the structural integrity would be compromised; as deck spreader beams during decommissioning; and as weight distribution on lightweight grillage applications or corroded deck areas, for example to support heavy equipment.

In addition, the lightweight nature of the beam has clear advantages and applications in other industries such as aerospace, civil engineering, and mechanical engineering. Use of the beam may permit the construction of lightweight supporting structures. The beam may also permit structures having an increased span for the same weight.

The various aspects of the present invention can be practiced alone or in combination with one or more of the other aspects, as will be appreciated by those skilled in the relevant arts. The various aspects of the invention can optionally be provided in combination with one or more of the optional features of the other aspects of the invention. Also, optional features described in relation to one aspect can typically be combined alone or together with other features in different aspects of the invention. Any subject matter described in this specification can be combined with any other subject matter in the specification to form a novel combination.

Various aspects of the invention will now be described in detail with reference to the accompanying figures. Still other aspects, features, and advantages of the

present invention are readily apparent from the entire description thereof, including the figures, which illustrates a number of exemplary aspects and implementations. The invention is also capable of other and different examples and aspects, and its several details can be modified in various respects, all
5 without departing from the scope of the present invention as defined by the claims. Accordingly, each example herein should be understood to have broad application and is meant to illustrate one possible way of carrying out the invention, without intending to suggest that the scope of this disclosure, including the claims, is limited to that example. Furthermore, the terminology and
10 phraseology used herein is solely used for descriptive purposes and should not be construed as limiting in scope. In particular, unless otherwise stated, dimensions and numerical values included herein are presented as examples illustrating one possible aspect of the claimed subject matter, without limiting the disclosure to the particular dimensions or values recited. All numerical values in
15 this disclosure are understood as being modified by "about". All singular forms of elements, or any other components described herein are understood to include plural forms thereof and vice versa.

Language such as "including", "comprising", "having", "containing" or "involving"
20 and variations thereof, is intended to be broad and encompass the subject matter listed thereafter, equivalents, and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps. Likewise, the term "comprising" is considered synonymous with the terms "including" or "containing" for applicable legal purposes. Thus, throughout the specification and
25 claims unless the context requires otherwise, the word "comprise" or variations thereof such as "comprises" or "comprising" will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

30 Any discussion of documents, acts, materials, devices, articles and the like is included in the specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these

matters formed part of the prior art base or were common general knowledge in the field relevant to the present invention.

In this disclosure, whenever a composition, an element or a group of elements is preceded with the transitional phrase "comprising", it is understood that we also contemplate the same composition, element or group of elements with transitional phrases "consisting essentially of", "consisting", "selected from the group of consisting of", "including" or "is" preceding the recitation of the composition, element or group of elements and vice versa. In this disclosure, the words "typically" or "optionally" are to be understood as being intended to indicate optional or non-essential features of the invention which are present in certain examples but which can be omitted in others without departing from the scope of the invention as defined by the claims.

References to directional and positional descriptions such as upper and lower and directions e.g. "up", "down" etc. are to be interpreted by a skilled reader in the context of the examples described to refer to the orientation of features shown in the drawings, and are not to be interpreted as limiting the invention to the literal interpretation of the term, but instead should be as understood by the skilled addressee.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a perspective view of a first beam in accordance with the invention, with a flange removed to show the inner wave structure and reinforcing members;

Figure 2 shows a second perspective view of the beam of Figure 1;

Figure 3 shows a close-up view of two apexes of the web of the beam of Figure 1 (flanges not shown) and reinforcing members;

Figure 4 shows a perspective view of the beam of Figure 1 with both flanges illustrated;

Figure 5 shows a perspective view of a second beam in accordance with the invention, where the web comprises cut-out portions;

Figure 6 shows a plan view of a beam in accordance with the invention, the beam comprising a complete web and illustrating the flattened retrofittable ends of the web;

Figure 7 shows an example of a substantially V-shaped component part of a web with cylindrical reinforcing members and slot welds; and

Figure 8 shows an example of a zigzag shaped component part of a web with cylindrical reinforcing members and slot welds.

DETAILED DESCRIPTION OF EXAMPLES OF THE INVENTION

Referring now to Figures 1-4, Figure 1 shows a partial view of a beam 1 with one flange removed for ease of observation of the web 11 and reinforcing members 14.

The web 11 is welded on seams 10w along the web 11 to a flange 12u. At each of the apexes 11c (where the term apex is used to include troughs from the point of view of the observer) of the web 11 a reinforcing member in the form of a cylinder 14 is welded to the web 11 with slot welds 10c and welded to the flange 12u by a further weld 10f. The welds 10w, 10f are repeated for the opposing flange 12l when it is affixed to form the beam 1.

At the interface of a cylinder 14 and the web 11, the thickness of the web 11 increases accordingly. The welds 10c between the cylinder 14 and the web 11 create sections with a greater thickness than the web 11 and the cylinder 14 individually. This stiffening mechanism further supports the loading capacity of the beam 1, in that the web 11 structurally supports the cylinders 14 while the cylinders 14 strengthen the web 11.

At the apexes 11c, the web turns around a tight circumference and traverses diagonally across the centre of the flange 12u (and flange 12l/the beam 1 when fully assembled) towards the other edge of flange 12u. The web sections 11f

between the apexes 11c of the web 11 are substantially linear. The web 11 undulates across approximately 90-95% of the entire width of the flange 12u in this example. The reinforcing cylinders 14 are positioned on the inner surfaces of the apexes 11c, and their location relative to the central axis of the flange 12u (and therefore the central axis of the beam 1) alternates with each turn of the web 11, along the longitudinal extent of the flange 12u. The horizontal distance between apexes 11c is constant along the length of the wave portion of the web 11.

Due to the wave profile, the beam 1 can have a deeper height between the upper 12u and lower 12l flanges, which increases the beam's 1 bending resistance while maintaining web buckling and shear resistance, and avoiding lateral torsional buckling. Furthermore, both flange 12u, 12l and web 11 thicknesses can be reduced, in order to lower beam weight while maintaining the beam's 1 ability to resist the applied transverse loads along its span. The configuration of the beam 1 according to the present invention enables lighter beams and/or longer beam spans to be provided without detriment to the beam's strength characteristics compared with known beams.

At the ends of the beam 1, the web 11 can in certain embodiments revert to a flat central web (see e.g. Figure 6) for a short distance to enable the beam 1 to be fitted into structural connections configured to receive I-beams without requiring the connective components throughout the larger structure to be changed out, further reducing cost.

Figure 4 illustrates a beam 1 in its assembled state with upper 12u and lower 12l flanges welded to the web 11 and the cylinders 14.

Figure 5 illustrates a further example of a web 111 in accordance with the present invention, where like features have had their reference numerals increased by 100 for ease of comparison to the features of Figures 1-4.

As illustrated in Figure 5, the flat portions 111f of the web 111 may be perforated by having apertures 111a cut or formed through them, for example moulded, punched, and so forth. In this example, the apertures 111a are approximately circular and arranged in a “gun barrel” configuration, with a single central aperture 111a surrounded by a concentric circle of 6 further apertures 111a. Other suitable configurations may of course be used where appropriate.

The apertures 111a serve the dual purpose of further reducing the weight of the beam 1 while also providing a route for services such as power conduits, communications conduits, and the like. Beams with the perforated web 111 may be particularly useful in commercial applications where a large number of services may require routing.

A beam may be formed with several separate sections of web connected together. For example, the components of the beam may be formed separately and fixed together.

Figure 6 shows an example of a beam, again with one flange 412u illustrated and one removed to show the web 411. The web 411 comprises reinforcing cylinders 414 as previously described. A portion 411e of the web 411 at both ends extends along, or parallel with, the longitudinal axis of the beam, providing the beam with a similar profile to a conventional I-beam at each end. This permits the beam to be retrofitted into connections for I-beams, thereby avoiding the need for new connections where, for example, this beam is used to replace a damaged or corroded conventional beam.

Figure 7 shows an example of a section of a wave-shaped web 211, fabricated as one component 202 in an approximate V-shape (with one “complete” apex 211c), where the reinforcing cylinders 214 are slot welded 210 to the apexes 211c, 211p of the web 211. The full length web is fabricated from several such component parts 202 connected together. Each end 211p of the web 211 is a partial circumference of a cylinder 214 and approximately half of the length of an apex 211c of the web 211. These component parts 202 can be welded or,

otherwise affixed together, to form the required length of web 211 for the required length of beam.

At the ends of the component parts 202, where sections 202 are joined together,
5 three welds 210 are used to fix the respective cylinder 214 both to the end 211p of the web 211, and to fix the ends 211p of two sections 202 together, while on the continuous portion 211c of the component part 202 the cylinder 214 is slot welded 210 to the adjacent flat portions 211f of the web 211.

10 The slot welds 210 are facilitated by chamfering the substantially triangular-shaped gap between the cylinder 214 and the flat portions 211f of the web 211 to create weld slots. The slot welds 210 can enhance the strength of the web 211, and therefore the beam, by creating an additional thickened section of wall on the inner side of the web 211 between the cylinder 214 and the web 211.

15 As previously described, at the ends of the complete beam the web 311 may be flattened out, for example to align with the central axis of the beam. The beams can thus be retrofitted into connections configured for convention beams such as I-beams or H-beams.

20 Alternatively, a web may be fabricated from larger component parts. Figure 8 shows a zigzag shaped component part 302 comprising more than one complete apex 311c. As before the ends 311p of the component parts 302 form a half-turn or half-apex. Two ends 311p are thus joined together by a weld 310 to form a
25 complete apex and continue the web 311. As many component parts 302 as required may be connected together.

The formation of the wave shape in the web 11, 111, 211, 311, 411 can be adjusted according to the thickness of the web material as required.

30 As previously described the examples illustrated in Figures 7 and 8 are also fixed e.g. welded to flanges on opposite sides of the web 211, 311 to form the beams.

In all examples of the invention the flanges 12u, 12l, 412u; the webs 11, 111, 211, 311, 411; and the reinforcing cylinders 14, 114, 214, 314, 414 are all interconnected such that they all act structurally as one structural unit, including in those examples where the beam is formed of modular component parts. All connections between parts facilitate load transfer between the structural elements of the flanges 12u, 12l, 412u; the webs 11, 111, 211, 311, 411; and the reinforcing cylinders 14, 114, 214, 314, 414.

Modifications and improvements may be made to the examples hereinbefore described without departing from the scope of the invention as defined by the claims.

Claims

1. A structural support member comprising at least two longitudinally extending flanges spaced apart from one another by an assembly comprising a web and at least one reinforcing member,
5 wherein the web comprises at least one wave-shaped web portion arranged perpendicularly to the flanges, and
wherein at least one apex of the at least one wave-shaped web portion comprises at least one reinforcing member.
10
2. A structural support member according to claim 1, wherein the structural support member is a beam.
3. A structural support member according to either of claims 1 or 2, wherein
15 the reinforcing member is substantially tubular.
4. A structural support member according to any preceding claim, wherein the reinforcing member is at least partially hollow along its length.
- 20 5. A structural support member according to any preceding claim, wherein the reinforcing members are positioned on the inner sides of the apexes of the web, closer to the central axis of the beam and/or flanges.
6. A structural support member according to any preceding claim, wherein
25 the or each apex encapsulates the reinforcing member.
7. A structural support member according to any preceding claim, wherein the shape of the wave in the web is substantially symmetrical.
- 30 8. A structural support member according to any preceding claim, wherein the distance between two apexes of the wave forming the web where the apexes are disposed on opposing sides of the flange is between 50-100% of the width of the flanges.

9. A structural support member according to any preceding claim, wherein the section of the web between each apex is substantially flat or linear.

5 10. A structural support member according to claim 2 or to any of claims 3 to 9 when dependent upon claim 2, wherein a portion of the web at one or both ends extend along the longitudinal axis of the beam.

10 11. A structural support member according to any preceding claim, wherein at the contact sites between the or each reinforcing member and the web, the joins between the reinforcing member and the web creates a portion of the assembly with a greater cross-sectional thickness than the web alone.

15 12. A structural support member according to any preceding claim, wherein the web comprises cut-out portions.

20 13. A structural support member according to any claim 2 or to any of claims 3 to 12 when dependent upon claim 2, wherein the components of the beam are formed as one integral piece.

14. A structural support member according to claim 2 or to any of claims 3 to 12 when dependent upon claim 2, wherein a beam is formed of several integrally-formed pieces connected together to extend the span of the beam.

25 15. A structural support member according to claim 14, wherein the components of the beam are formed separately and fixed together.

30 16. A structural support member according to either of claims 14 or 15, wherein the web is fabricated from multiple modular sections, each comprising one whole apex and two half apexes.

17. A structural support member according to claim 3, or to any of claims 4 to 16 when dependent upon claim 3, wherein the tubular comprises a cylinder and

at the locus where the web meets the reinforcing member there is a triangular space formed between the curved side of the cylinder and the flat portion of the web, just before the web begins to curve around the cylinder.

- 5 18. A structural support member according to any of claims 14 to 16 or to claim 17 when dependent upon any of claims 14 to 16, wherein larger modular sections of the web are fabricated by zigzag shaped modular sections comprising more than one complete turn.
- 10 19. A structural support member according to claim 2 or to any of claims 3 to 18 when dependent upon claim 2, wherein one or more beams are incorporated into modular interlocking sections.
- 15 20. A structural support member according to claim 19, wherein the said modular interlocking sections comprise the same or a similar area as shipping containers.
- 20 21. A structural support member according to either of claims 19 or 20, wherein the modular interlocking sections are supplied and fitted in modular sections to create the desired size of deck floor sections.
- 25 22. A structural support member according to any of claims 19 to 21, wherein the modular interlocking sections comprise the beam according to the invention alternating with a conventional beam to form the overall modular interlocking section.

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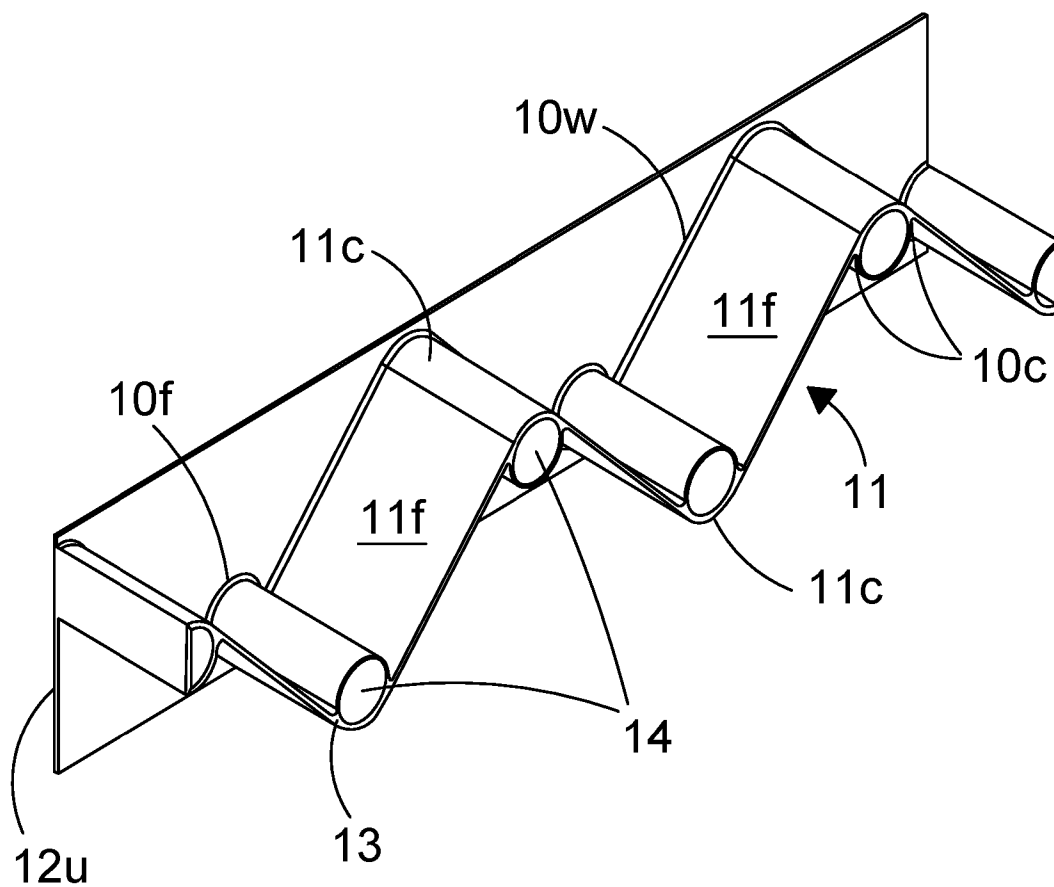


FIG. 1

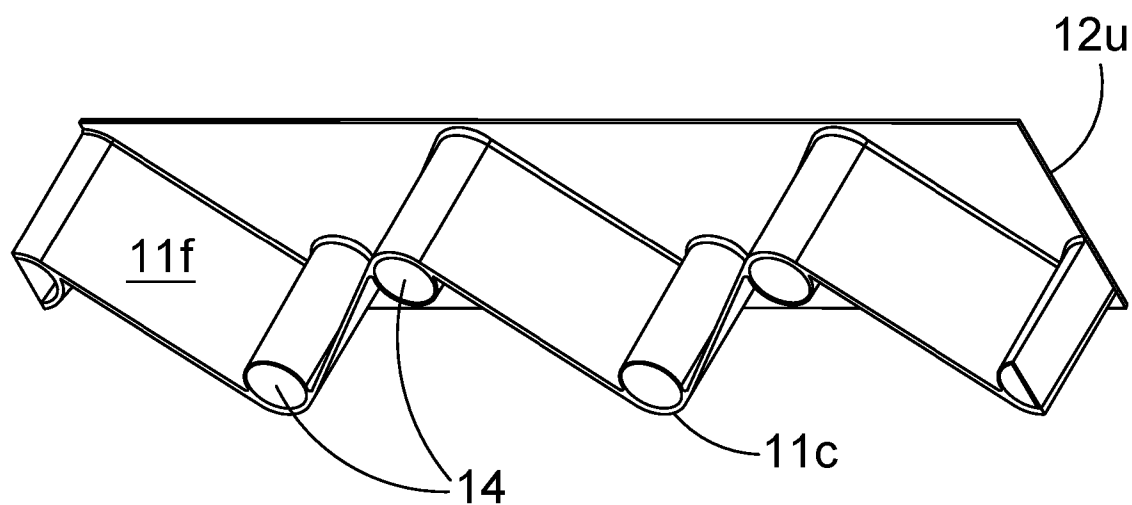


FIG. 2

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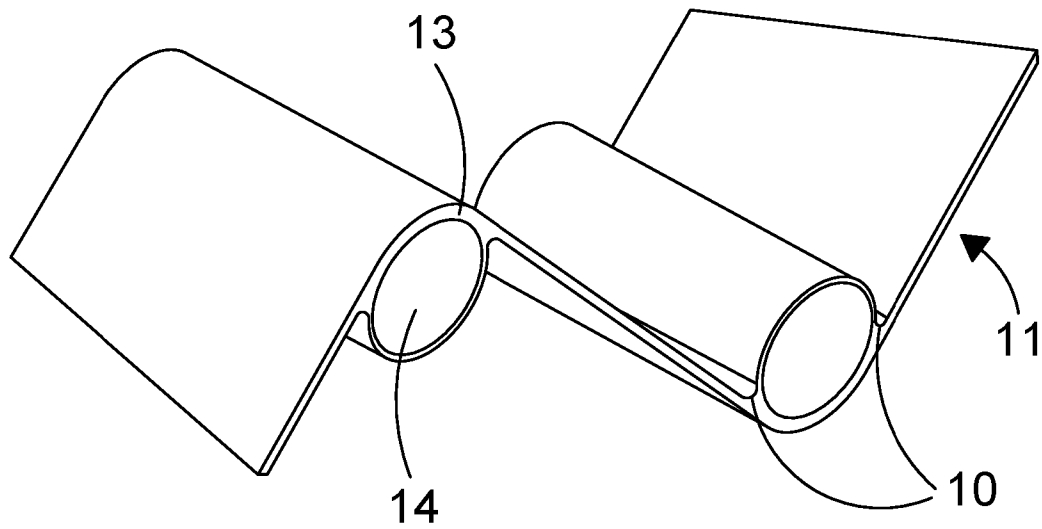


FIG. 3

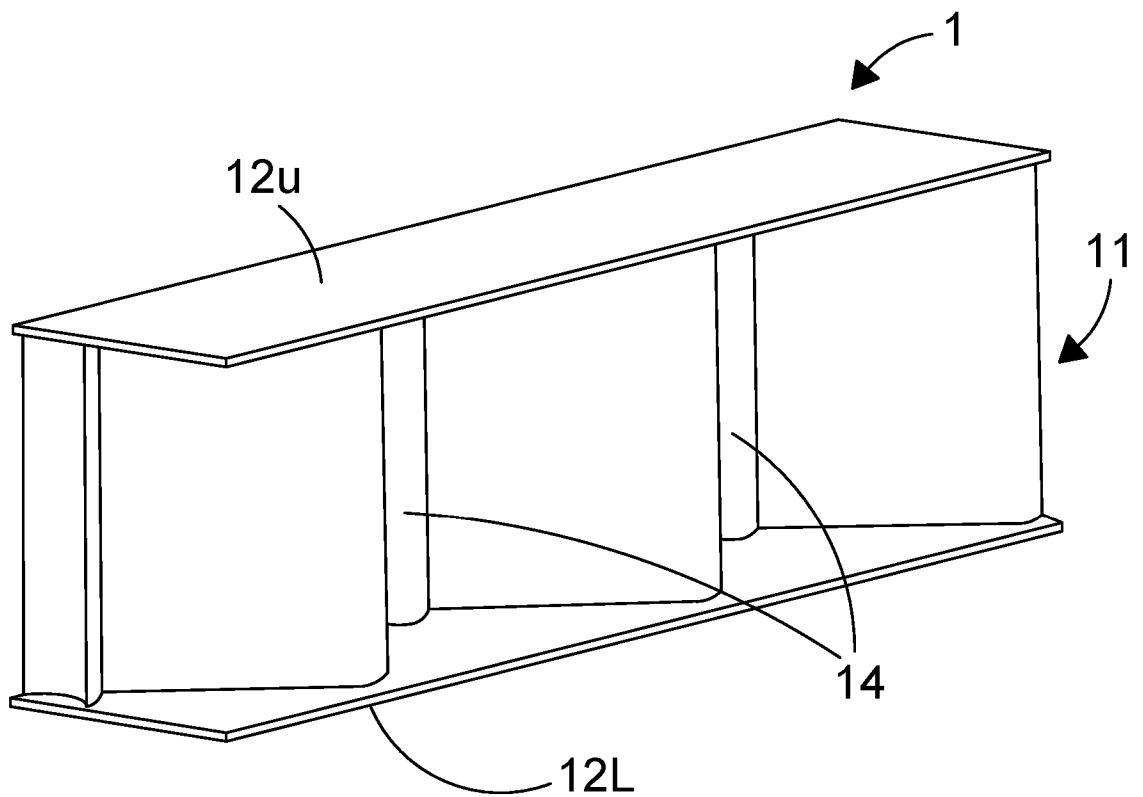


FIG. 4

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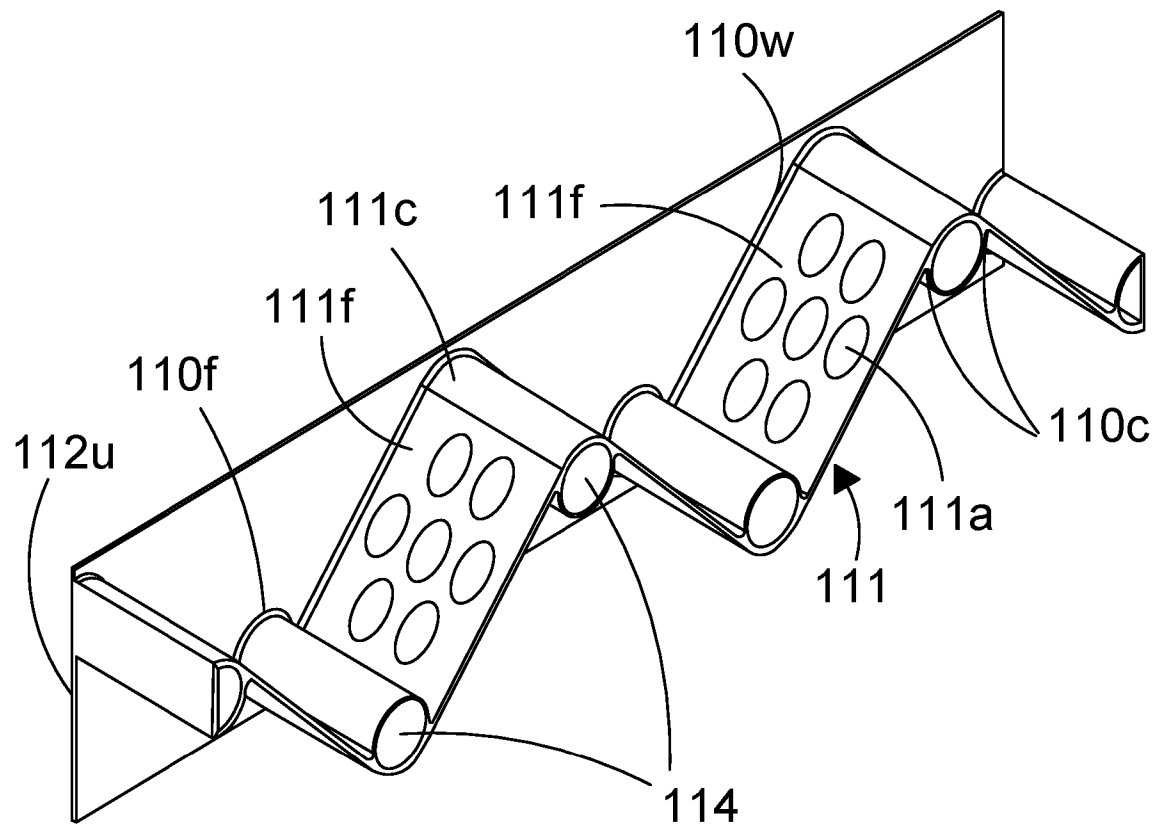


FIG. 5

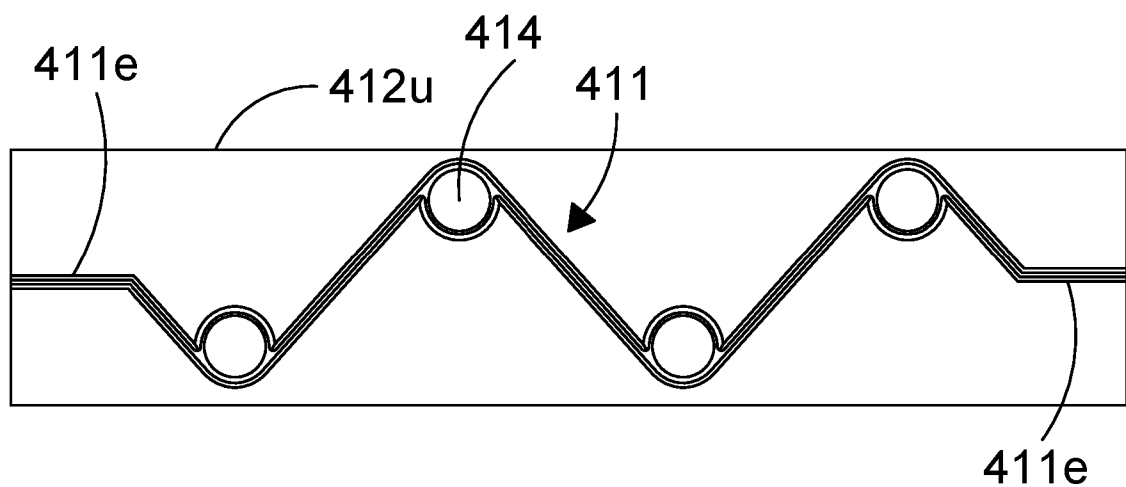


FIG. 6

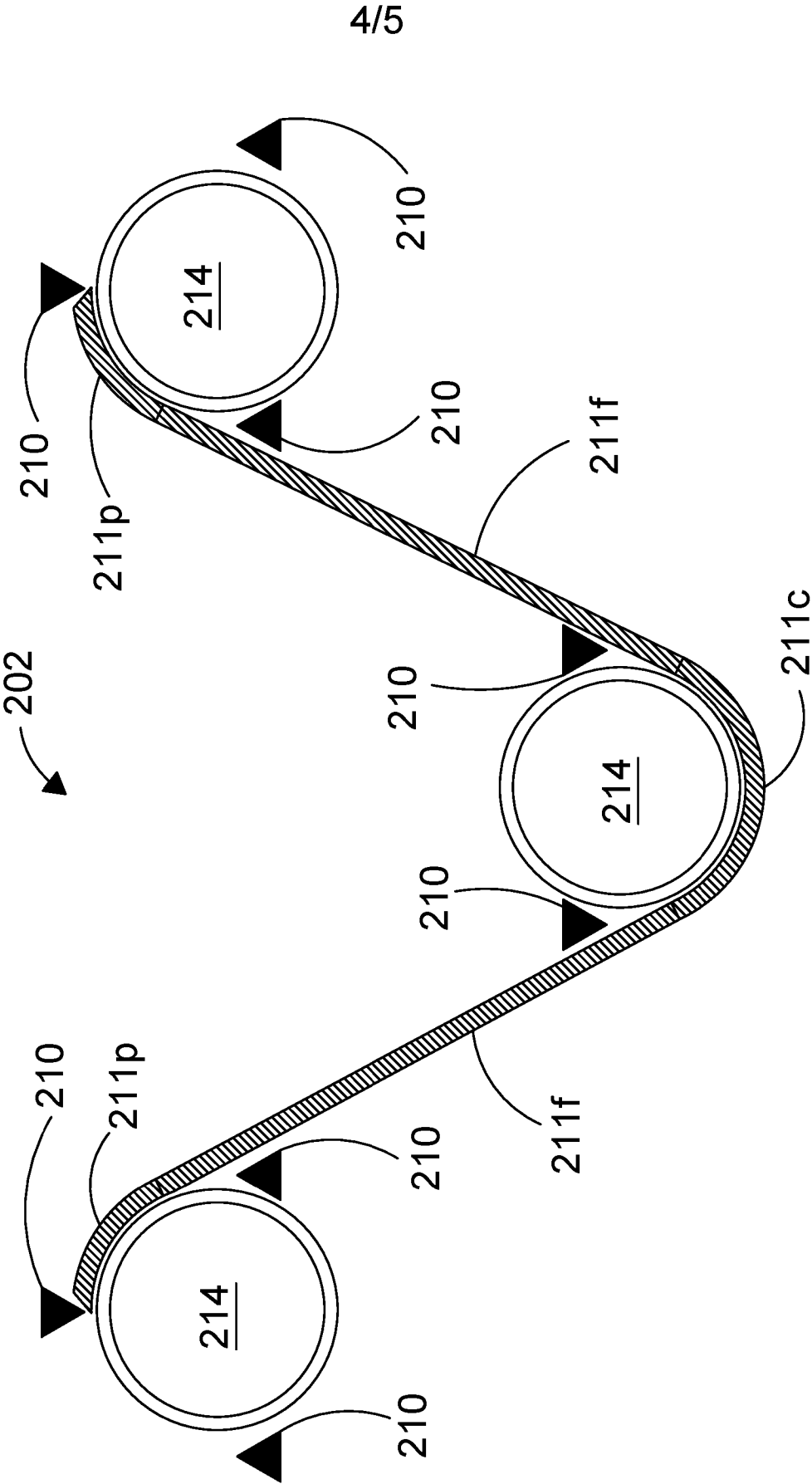


FIG. 7

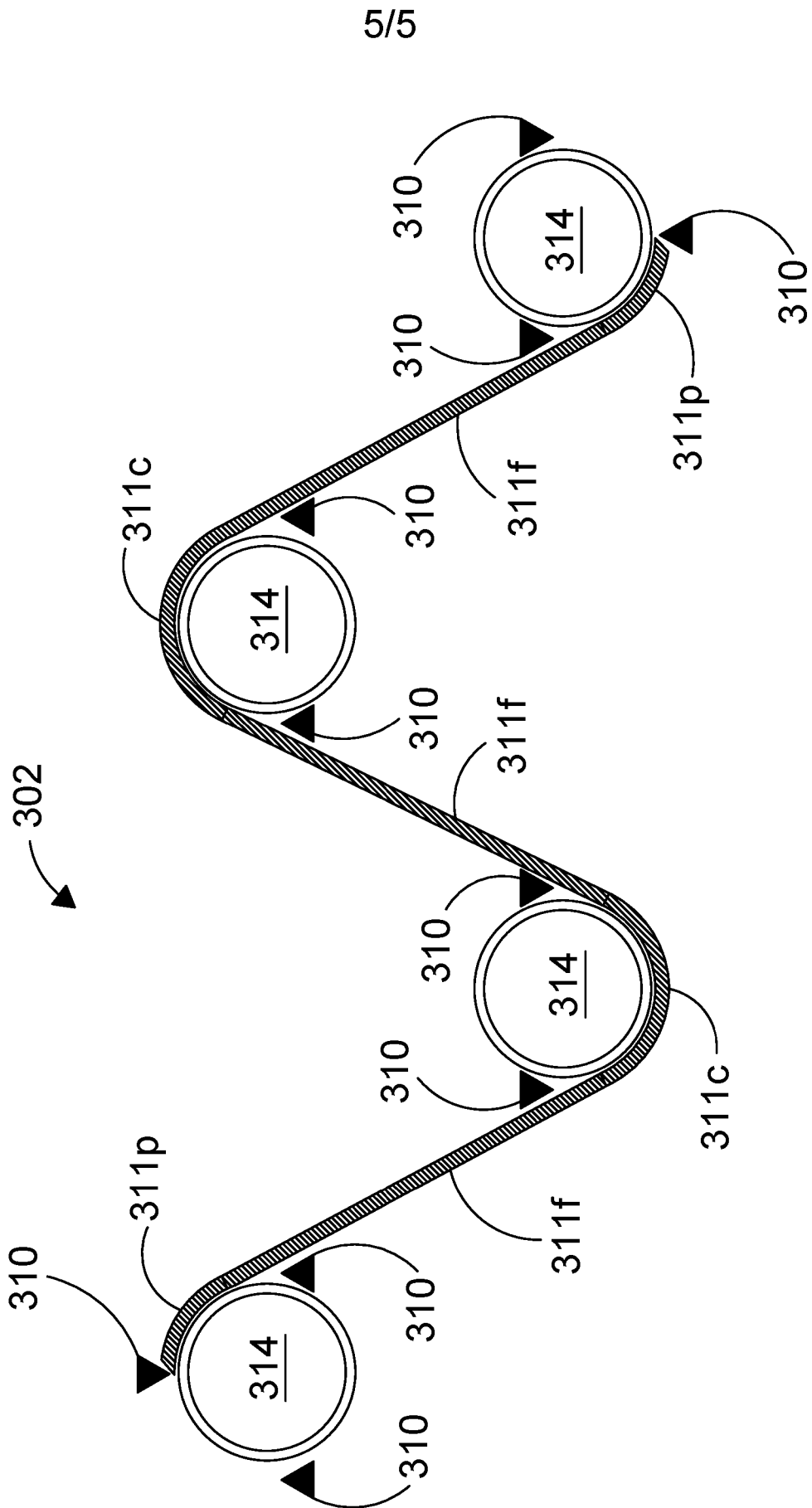


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2020/051046

A. CLASSIFICATION OF SUBJECT MATTER

INV. E04C3/07 E04C3/28 E04C3/29
 ADD. E04C3/06 E04C3/08 E04C3/09 E04C3/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/16197 A1 (LOCKHEED CORP [US]) 28 February 2002 (2002-02-28)	1-3,5-8, 10-16, 18-22
A	figure 6b -----	4,9,17
X	WO 2009/124356 A1 (QLD STEEL PTY LTD [AU]; GARRY MATTHEW JOHN JOSEPH [AU]) 15 October 2009 (2009-10-15)	1-10, 12-15, 18-21
A	figure 5 -----	11,16, 17,22
A	US 5 190 803 A (GOLDBACH HUBERT [DE] ET AL) 2 March 1993 (1993-03-02) figure 1 -----	1-22



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

21 July 2020

Date of mailing of the international search report

30/07/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2020/051046

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