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(54) Title: APPARATUS AND METHOD FOR CORRUGATING SHEET MATERIAL

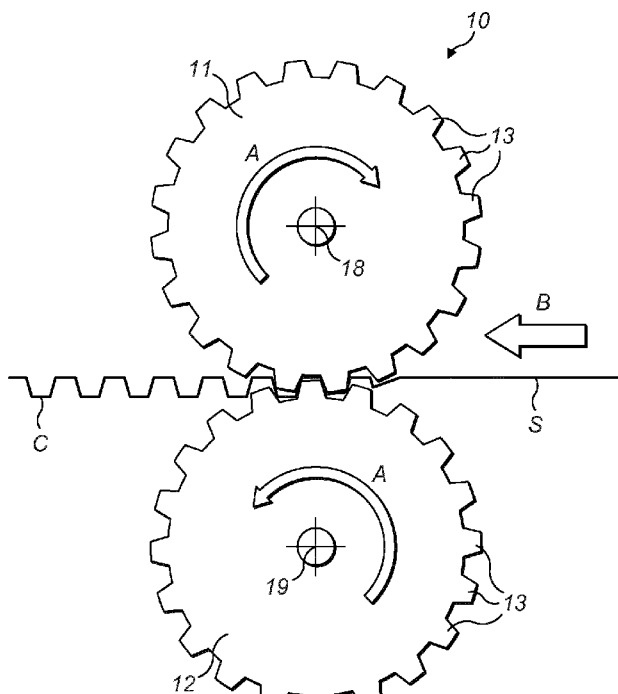


FIG. 1

(57) Abstract: Apparatus and Method for Corrugating Sheet Material An apparatus for corrugating a continuous sheet material. The apparatus comprises first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth. The teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face. A method of corrugating a sheet material using such an apparatus is also provided.



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Apparatus and Method for Corrugating Sheet Material

Technical Field

This specification relates to an apparatus and method for corrugating sheet material
5 such as, but not limited to, paper or card.

Background

Containers and packaging may be made of paper or card, or other sheet material, which
may be folded into the desired shape and held together or in place with adhesive or
10 other securing means. To facilitate the sheet material being folded into the desired
shape, or to provide a distinctive appearance or function, it may be desirable to
corrugate the sheet material.

Summary

15 In this specification there are described embodiments of an apparatus for corrugating a
continuous sheet material comprising first and second members having toothed
surfaces in meshing engagement such that a planar sheet material may be fed between
the first and second surfaces and shaped into a corrugated configuration by, and
corresponding to, the meshing teeth, wherein the teeth on the first and second
20 members each comprise a top face and opposing side faces, and edges where the side
faces meet the top face.

The teeth may be angular, in that the top face and opposing side faces meet at an angle.
This provides the advantageous angular corrugated configuration of sheet material, as
25 opposed to a continuous smooth sinuous corrugated configuration. In cross-section,
the internal angle between the top face and each of the side faces may be around 120
degrees, and the teeth on the first and second surfaces may be shaped as half of a
hexagon in cross-section.

30 At least one of the first and second members may comprise a rotatable roller.

At least one of the first and second members may comprise a continuous belt.

The first member may be moveable towards and away from the second member to alter
35 the degree of meshing engagement between the toothed surfaces of the first and second

members.

The surface of at least one of the first and second members may be adapted to reduce the friction between said surface and the sheet material being corrugated as the sheet
5 material is deformed between the first and second members.

The surface of at least one of the first and second members may include a friction-reducing coating.

10 The surface of at least one of the first and second members may include a plurality of apertures therein and the apparatus may be provided with a source of compressed air fluidly connected to said surface to deliver compressed air through the apertures to create an air cushion between said surface and the sheet material.

15 The surface of at least one of the first and second members may include a plurality of roller elements on the teeth to assist the sheet material to move over the surface of said teeth.

The roller elements may be disposed along the tooth edges where the top face meets at
20 least one of the side faces.

At least one of the first and second members may be configured to further promote deformation of a sheet material as the sheet material is passed between the first and second surfaces.

25 The surface of at least one of the first and second members may include a plurality of apertures therein and the apparatus is provided with a source of steam fluidly connected said surface to deliver steam through the apertures to the sheet material.

30 The surface of at least one of the first and second members may include a plurality of apertures therein and the apparatus is provided with a vacuum source fluidly connected said surface to apply a vacuum to the air holes to draw the sheet material against said surface.

35 The teeth on at least one of the first and second members may include one or more blades projecting therefrom configured to score a sheet material at intended fold lines

as it is fed between the first and second members. The blades may be disposed where the top face meets at least one of the side faces of the respective teeth.

5 The apparatus may further comprise a steam source configured to apply steam to a sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation.

10 The apparatus may further comprise a heat source configured to heat a sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation.

15 In this specification there is also described an apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the surface of at least one of the first and second members is adapted to reduce the friction between said surface and the sheet material being corrugated as the sheet material is deformed between the first and second members.

25 In this specification there is also described an apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the surface of at least one of the first and second members includes a plurality of apertures therein and the apparatus is provided with a source of steam fluidly connected said surface to deliver steam through the apertures to the sheet material.

35 In this specification there is also described an apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a

top face and opposing side faces, and edges where the side faces meet the top face, and wherein the surface of at least one of the first and second members includes a plurality of apertures therein and the apparatus is provided with a vacuum source fluidly connected said surface to apply a vacuum to the air holes to draw the sheet material
5 against said surface.

In this specification there is also described an apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and
10 second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the teeth on at least one of the first and second members includes one or more blades projecting therefrom configured to score a sheet material at intended fold lines
15 as it is fed between the first and second members

In this specification there is also described a method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and
20 second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the sheet material is deformed into a corrugated configuration by, and corresponding to, the meshing teeth.

The corrugations formed in the sheet material may be shaped as half of a hexagon in
25 cross-section.

The method may comprise moving the first member towards and away from the second member to alter the contact force with which the surface of the first member meshes with the surface of the second member.

30 The first and second members may comprise rotatable rollers, and the method may comprise moving the first member towards the second member as each successive tooth on the first member is received within a corresponding space between teeth on the second member as the first and second members rotate in meshing engagement.

35

The method may comprise applying a vacuum through apertures in the surface of one of the first and second members to draw the sheet material against said surface.

5 The method may comprise applying the vacuum to draw the sheet material against said surface prior to deforming the sheet material between the first and second members.

10 The method may comprise providing compressed air through apertures in the surface of one of the first and second members to create an air cushion between said surface and the sheet material to reduce the friction therebetween as the sheet material is being corrugated.

15 The method may comprise providing roller elements on the teeth on the surface of at least one of the first and second members to assist the sheet material to move over the surface of said teeth.

The roller elements may be provided where the top face meets at least one of the side faces of the respective teeth.

20 The method may comprise applying steam to the sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation. The steam may be delivered to the sheet material through a plurality of apertures in the surface of at least one of the first and second members.

25 The method may comprise heating the sheet material before or during passage between the first and second member to promote the deformation of the sheet material to a corrugated formation.

30 The method may comprise scoring the sheet material at intended fold lines as it is fed between the first and second members using blades projecting from the teeth on at least one of the first and second members.

35 In this specification there is also described a method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the

side faces meet the top face, and wherein the sheet material is deformed into a corrugated configuration by, and corresponding to, the meshing teeth, the method comprising applying steam to the sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation and wherein the steam is delivered to the sheet material through a plurality of apertures in the surface of at least one of the first and second members.

In this specification there is also described a method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the sheet material is deformed into a corrugated configuration by, and corresponding to, the meshing teeth, the method comprising applying a vacuum through apertures in the surface of one of the first and second members to draw the sheet material against said surface.

In this specification there is also described a method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the sheet material is deformed into a corrugated configuration by, and corresponding to, the meshing teeth, the method comprising scoring the sheet material at intended fold lines as it is fed between the first and second members using blades projecting from the teeth on at least one of the first and second members.

Brief Description of the Drawings

Figure 1 shows a schematic view of an apparatus according to a first embodiment;
Figure 2 shows an enlarged view of a corrugating roller of the apparatus in Figure 1;
Figure 3 shows a schematic view of an apparatus according to a second embodiment;
Figure 4 shows a schematic view of an apparatus according to a third embodiment;
Figure 5 shows a schematic view of an apparatus according to a fourth embodiment;
Figure 6 shows a schematic view of an apparatus according to a fifth embodiment;
Figure 7 shows a schematic view of an apparatus according to a sixth embodiment;
Figure 8 shows an enlarged view of a portion of a corrugating roller according to a seventh embodiment;

Figure 9 shows an enlarged view of a portion of a corrugating roller according to an eighth embodiment;

Figure 10 shows an enlarged view of a portion of a corrugating roller according to a ninth embodiment;

5 Figure 11 shows an enlarged view of a portion of a corrugating roller according to a tenth embodiment;

Figure 12 shows an enlarged view of a portion of a corrugating roller according to an eleventh embodiment;

10 Figure 13 shows an enlarged view of a portion of a corrugating roller according to a twelfth embodiment; and

Figure 14 shows an enlarged view of a portion of a corrugating roller according to a thirteenth embodiment.

Detailed Description

15 Referring to Figure 1, there is shown a first embodiment of an apparatus 10 for corrugating sheet material such as paper or card, which comprises first and second corrugating rollers 11, 12, each having protruding teeth 13 around their periphery. The corrugating rollers 11, 12 are positioned adjacent each other such that their respective teeth 13 mesh, and the corrugating rollers 11, 12 are rotatable in opposite directions, as
20 shown by arrows A, about respective axes 18, 19. In use, a flat sheet of board or paper S is fed between the meshing teeth 13, as shown by arrow B, and is pressed into a corrugated form.

The teeth 13 of the corrugating rollers 13 are advantageously configured to create an
25 angular corrugation to the sheet S as it is pressed between them. An enlarged view of a section of one of the corrugation rollers 11/12 is shown in Figure 2, showing the teeth 13 in more detail. Each tooth 13 is shaped with an angular profile, and comprises a top land 14, opposite side faces 15, and a bottom land 16 either side of the tooth 13 which corresponds to the root circle 17 of the roller 11, 12. An angular edge is formed where
30 the side faces 15 meet the top land 14 and the bottom land 16 to provide the desired angular corrugation. The apparatus is advantageously configured to provide a generally hexagonal-profile corrugation and so the angle θ between the top land 14 and the side faces 15 of each tooth is 120° and the angle ϕ between the bottom land 16 and the side faces is 120° .

An apparatus 20 according to a second embodiment is shown in Figure 3 and is similar to the apparatus in Figures 1 and 2, and like features retain the same reference numerals. One difference between the apparatus of the second embodiment is that the first corrugation roller 11 is moveable towards and away from the second corrugation roller 12 as the first corrugation roller 11 rotates, as shown by arrow F, and the dotted image of the first corrugation roller 11, in Figure 3. This can be achieved by the first corrugation roller being mounted on a moveable chassis which is moveable towards and away from the second corrugation roller by appropriate means, such as a piston or an eccentric cam acting on the spring-biased chassis. The motion of the first corrugation roller 11 towards and away from the second corrugation roller 12 is advantageously a linear reciprocating movement such that the rotational axes 18, 19 of the first and second corrugation rollers 11, 12 remain parallel, but the distance between the axes 18, 19 varies. This results in the first corrugation roller 11 intermittently exerting an increased force on the sheet S as it passes between the rollers 11, 12, improving the corrugated pattern being permanently imparted to the sheet S.

The first corrugation roller 11 may not move much, or at all, but may be configured so that it is intermittently pressed into engagement with the second corrugation roller 12. Alternatively, the corrugation rollers may continuously be pressed together and the force with which they are pressed together may be intermittently increased and decreased as the rollers 11, 12 rotate. To optimise the effectiveness of the reciprocating motion of the first corrugation roller 11, or the intermittent forcing of the first roller 11 towards the second roller, the movement/force application can be timed such that a force in a direction towards the second corrugation roller 12 occurs when each tooth 13 on the first roller 11 is located squarely in the bottom land 16 of the second roller 12. In addition, the movement or increased force advantageously occurs as each tooth 13 of the first roller 11 locates in the respective bottom land 16 of the second roller. Therefore, the frequency (Hz) of movement/force application of the first corrugation roller is $t \times \omega$ where 't' = no. of teeth around the circumference of the first corrugation roller and ' ω ' = rotational speed of the first corrugation roller (in revolutions per second).

An apparatus 30 of a third embodiment is shown in Figure 4 and comprises first and second corrugation members. The first corrugation member is a roller 11 as with the first and second embodiments, but instead of a second corrugation roller 12, the second corrugation member comprises a corrugation belt 31 which rotates over belt rollers 32,

33. The corrugation belt 31 is itself corrugated in a semi-hexagonal configuration and the corrugations mesh with the teeth 13 of the first corrugation roller 11. The first roller is shown in Figure 4 as meshing with the corrugation belt 31 mid-way between the two belt rollers 32, 33, although the invention is not limited to this configuration and
5 instead, the first roller may mesh with the corrugation belt 31 at any point between the belt rollers 32, 33, or even in line with one of the belt rollers 32, 33. In operation, the flat sheet S is fed between the first corrugation roller 11 and the corrugation belt 31 and is deformed between the teeth 13 of the first roller 11 and the corrugation belt 31 into a corrugated sheet C.

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Although not shown in Figure 4, the corrugation belt 31 may pass over a solid flat surface between the belt rollers 32, 33, such as a plate, so that the first roller 11 has a surface to press against to ensure the corrugations are imparted to the sheet S, and so that the belt 31 doesn't simply deflect away from the first roller 11.

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An apparatus 40 of a fourth embodiment is shown in Figure 5 and is similar to that of the third embodiment, and like features retain the same reference numerals. However, one difference of the apparatus of the fourth embodiment is that, as well as being rotatable, the first corrugation roller 11 is moveable toward and away from the
20 corrugation belt, shown by arrow F and the dotted image of the first corrugation roller 11, in the same manner as the first corrugation roller 11 of the apparatus 20 of the second embodiment, with the same advantageous benefits as described above.

An apparatus 50 of a fifth embodiment is shown in Figure 6 and is similar to the
25 apparatus 30 of the third embodiment, and like features retain the same reference numerals. One difference of the fifth embodiment over the third embodiment however, is that the first corrugation roller is replaced with a second corrugation belt 51 which rotates over second belt rollers 52, 53. The second corrugation belt 51 is itself corrugated in a semi-hexagonal configuration and the corrugations mesh with the
30 corrugations of the other, first corrugation belt 31. In operation, the flat sheet S is fed between the first and second corrugation belts 31, 51 and is deformed therebetween into a corrugated sheet C.

An apparatus 60 of a sixth embodiment is shown in Figure 7 and is similar to the
35 apparatus 50 of the fifth embodiment, and like features retain the same reference numerals. One difference however, of the sixth embodiment over the fifth embodiment

is that the second corrugation belt 51 and belt rollers 52, 53 are moveable toward and away from the first corrugation belt 31, shown by arrow F and the dotted image of the second corrugation belt 51 and belt rollers 52, 53, in the same manner as the first corrugation roller 11 described previously. In this embodiment, the mechanism of the second corrugation rollers 52, 53 and corrugation belt 51 may be mounted on a single moveable chassis which may include means to reciprocate the chassis toward and away from the first corrugation belt 31 such as those described above, for example hydraulic/pneumatic pistons or being spring biased in one direction and acted upon by a rotating eccentric cam.

10

It will be appreciated that as a sheet material to be corrugated is deformed between the corrugation rollers 11, 12 or corrugation belts 31, 51 in the apparatuses described above, they are subject to frictional forces which may damage or tear the material. It is therefore desirable to reduce this friction between the contact surfaces of the rollers 11, 12/belts 31, 51 and the sheet material. Accordingly, embodiments may include friction-reducing means on one or both of the surfaces of the corrugation rollers 11, 12 or corrugation belts 31, 51.

15

Figure 8 shows an enlarged view of a corrugation roller 71 of an apparatus 70 of a seventh embodiment, which includes a first friction-reducing means. The apparatus 70 of the seventh embodiment is generally similar to that of the first embodiment and comprises first and second meshing corrugation rollers (only a portion of the first corrugation roller 71 is shown) between which planar sheet material S is fed and deformed into a corrugated form. One difference with the corrugation rollers of the apparatus 70 of the seventh embodiment is that outer surface is provided with a low-friction coating 72. Such coating may be, for example, PTFE. This reduced friction coating encourages the sheet material to slide over the teeth 13 to deform between the teeth of the corrugation rollers 71 without tearing under the force exerted by the rollers 71.

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Figure 9 shows an enlarged view of a corrugation roller 81 of an apparatus 80 of an eighth embodiment, which is generally similar to that of the first embodiment and comprises first and second meshing corrugation rollers (only a portion of the first corrugation roller 81 is shown) between which planar sheet material S is fed and deformed into a corrugated form. However, one difference with the apparatus 80 of the eighth embodiment is that it includes an alternative friction-reducing means

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comprising small needle rollers along the edges of the teeth 13 between the top land 14 and each side face 15 of each tooth 13. As a planar sheet material S is fed between the corrugation rollers 81 and deformed therebetween, it is able to roll over the needle rollers 82 on the teeth to avoid tearing. It will be appreciated that the corrugation roller 81 shown in Figure 9 is not drawn to scale and may be wider than shown to accommodate wider sheet material S. Also, it may be advantageous for sheet material processed using such corrugation rollers 81 not to extend right to the very edges of the corrugation rollers (i.e. to be narrower than the width of the corrugation rollers) to avoid damage by the edge portions of the teeth 13 where the needle rollers 82 end.

Although the embodiment shown in Figure 9 comprises needle rollers 82 only at the edges between the top land 14 and side faces 15 of the teeth 13, in an alternative variation of this embodiment (not shown), needle rollers may also be provided where the bottom lands 16 meet the side faces 15 of each tooth 13.

Figure 10 shows an enlarged view of a corrugation roller 91 of an apparatus 90 of a ninth embodiment, which is generally similar to that of the first embodiment and comprises first and second meshing corrugation rollers (only a portion of the first corrugation roller 91 is shown) between which planar sheet material S is fed and deformed into a corrugated form. However, one difference with the apparatus 90 of the ninth embodiment is that it includes an alternative friction-reducing means comprising an air-cushion generating means. The corrugation roller 91 is hollow and includes a plurality of apertures 92 across its outer surface. Its interior is fluidly coupled to a source of compressed air or gas P, so that air is forced out of the apertures 92 across the entire surface of the corrugation roller 91. These form air jets 93 which create an air-cushion over the surface of the corrugation roller 91 that reduced the friction between the roller surface and the sheet material S and encourages a sheet material S to deform between the teeth 13 of the corrugation rollers 91 without tearing under the force exerted by the rollers 91.

Figure 11 shows an enlarged view of a corrugation roller 101 of an apparatus 100 of a tenth embodiment, which is generally similar to that of the first embodiment and comprises first and second meshing corrugation rollers (only a portion of the first corrugation roller 101 is shown) between which planar sheet material S is fed and deformed into a corrugated form. However, one difference with the apparatus 100 of the tenth embodiment is that it includes a vacuum-generating means. The corrugation

roller 101 is hollow and it includes a plurality of apertures 102 across its outer surface. Its interior is fluidly coupled to a vacuum source V, so that air is sucked in through the apertures 102 across the entire surface of the corrugation roller 101 which draws a sheet material S to deform against the surface of the corrugation roller 101 over and between
5 the teeth 13, as shown by arrows D in Figure 11. As the sheet material S is encouraged to deform to the contours of the corrugation roller 101, less stress is exerted on the sheet material S by the meshing teeth of the other corrugation roller, reducing the friction and likelihood of damage or tearing to the sheet material S.

10 It may be advantageous in use of the apparatus 100 of this embodiment that the sheet material S encounters the vacuum corrugation roller 101 first to enable the sheet to be drawn against the vacuum roller 101 before the other meshing corrugation roller exerts a corrugating force on the material sheet S by the meshing teeth 13. This may be achieved, for example, by combining this embodiment with a reciprocating corrugating
15 roller, as with the apparatus 20 of the second embodiment, which moves towards and away from the vacuum-generating corrugating roller 101 so the sheet material is able to be drawn against the surface the vacuum corrugating roller 101 before the reciprocating corrugating roller moves down to mesh against it. Alternatively, or in addition, the sheet material may be fed to the meshing corrugating rollers such that it encounters the
20 surface of the vacuum-generating roller 101 prior being fed between the rollers, rather than being fed directly into the nip of the meshing corrugating rollers.

Figure 12 shows an enlarged view of a corrugation roller 111 of an apparatus 110 of an eleventh embodiment, which is generally similar to that of the first embodiment and
25 comprises first and second meshing corrugation rollers (only a portion of the first corrugation roller 111 is shown) between which planar sheet material S is fed and deformed into a corrugated form. However, one difference with the apparatus 110 of the eleventh embodiment is that it includes a plurality of scoring blades 112 (not drawn to scale) disposed along the edges of the teeth 13 between the top land 14 and the side
30 faces 15. These blades 112 act to create a shallow score line in the sheet material S as it is deformed between the corrugation rollers which results in sharper folds in the resulting corrugated sheet C, and weakens the sheet material at the folds so that the resulting corrugated sheet remains in the desired folded configuration and the folds are less prone to flattening out.

The blades 112 may be continuous elongate blades across the entire width of each tooth 13, or may comprise a plurality of blades along each tooth edge. The blades 112 may also be spring loaded within the teeth 13 so that they retract into the teeth if acted upon by a pre-determined pressure to avoid scoring the sheet material S too deeply or
5 entirely therethrough.

Figure 13 shows an enlarged view of a corrugation roller 121 of an apparatus 120 of a twelfth embodiment, which is generally similar to that of the first embodiment and comprises first and second meshing corrugation rollers (only a portion of the first
10 corrugation roller 121 is shown) between which planar sheet material S is fed and deformed into a corrugated form. However, one difference with the apparatus 120 of the twelfth embodiment is that it includes a steam-generating means. The corrugation roller 121 is hollow and it includes a plurality of apertures 122 across its outer surface. Its interior is fluidly coupled to a steam source H, so that steam is ejected through the
15 apertures 122 across the surface of the corrugation roller 121. The steam on the sheet material S causes the material to soften and therefore makes it easier for the sheet material S to deform against the surface of the corrugation roller 121 over and between the teeth 13 with less stress being exerted on the sheet material S reducing the likelihood of damage or tearing to the sheet material S.

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In the twelfth embodiment, one or both corrugation rollers may include steam generating means as described above. Furthermore, the rollers 121 may be configured such that steam is only ejected through the apertures 122 over a portion of the outer surface of the roller 121 to avoid excessive steam being ejected where there is no sheet
25 material.

In an alternative embodiment, steam may be used to soften the sheet material S prior to being deformed into a corrugated form by the corrugation rollers 11, 12, or corrugation belts 31, 51, although rather than the steam being provided from within the corrugation
30 roller(s) as with the twelfth embodiment, it may be provided from an external source, e.g. a steam jet or nozzle directed onto the sheet material S, prior to or during the passage of the sheet material S through the apparatus.

In a further alternative embodiment, heat may be applied to the sheet material S prior
35 to or during it being deformed into a corrugated form. Figure 14 shows an enlarged view of a corrugation roller 131 of an apparatus 130 of a thirteenth embodiment, which

is generally similar to that of the first embodiment and comprises first and second meshing corrugation rollers (only a portion of the first corrugation roller 131 is shown) between which planar sheet material S is fed and deformed into a corrugated form. However, one difference with the apparatus 130 of the thirteenth embodiment is that it includes a heat-generating means in the form of heating elements 132 within the roller 131. The heating elements 132 may be electrically powered heating elements. The heat applied to the sheet material S causes the material to soften and therefore makes it easier for the sheet material S to deform against the surface of the corrugation roller 131 over and between the teeth 13 with less stress being exerted on the sheet material S reducing the likelihood of damage or tearing to the sheet material S.

Although in the thirteenth embodiment, the heat is provided from the corrugation roller 131, in an alternative embodiment, heat may be provided from an external source to soften the sheet material S prior to being deformed into a corrugated form by the corrugation rollers 11, 12, or corrugation belts 31, 51. In such an embodiment, the heat may be provided from an external source such as an external heating element or hot air jet directed onto the sheet material S, prior to or during the passage of the sheet material S through the apparatus.

In the various embodiments described above, where one roller is described as having a particular function, such as steam generation, having blades, low-friction coating, heating elements, needle rollers, etc, it is intended within the scope of the invention that both rollers could be provided with such function to improve the efficiency and effectiveness of the apparatus. Furthermore, such functions are described above in the context of apparatuses with corrugation rollers, although the invention is intended to equally cover such functions applied to apparatuses having corrugations belts instead of, or as well as, rollers. For example, a corrugation belt could be provided with a plurality of apertures through which steam, a vacuum or compressed air is applied, or the belt surface could be provided with knife blades on the teeth edges, low-friction coating, needle rollers or heating elements. In the case of the vacuum source, the corrugation belt(s) could be made of a porous material instead of, or as well as having a plurality of apertures formed therein.

It is intended within the scope of the invention that any combination of non-mutually exclusive features of the embodiments described above may be provided in combination. For example, an apparatus may comprise one corrugation roller or belt

having apertures through which steam, a vacuum or compressed air is applied, or teeth with knife blades on the tooth edges, low-friction coating, needle rollers or heating elements, and the other of the corrugation roller or belt could be provided with a different one of the above functions.

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It is intended that the embodiments described above could be used to corrugate a number of different sheet materials, such as, but not limited to, paper, card board, foil or film. The sheet material to be corrugate may be of a range of different weights, but it is particularly intended to be applicable to sheet material of between 40g/sq. metre –
10 320g/sq. metre.

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In order to address various issues and advance the art, the entirety of this disclosure shows by way of illustration various embodiments in which the claimed invention(s) may be practiced and provide for superior apparatus and method for corrugating sheet material. The advantages and features of the disclosure are of a representative sample
15 of embodiments only, and are not exhaustive and/or exclusive. They are presented only to assist in understanding and teach the claimed features. It is to be understood that advantages, embodiments, examples, functions, features, structures, and/or other aspects of the disclosure are not to be considered limitations on the disclosure as
20 defined by the claims or limitations on equivalents to the claims, and that other embodiments may be utilised and modifications may be made without departing from the scope and/or spirit of the disclosure. Various embodiments may suitably comprise, consist of, or consist essentially of, various combinations of the disclosed elements, components, features, parts, steps, means, etc. In addition, the disclosure includes
25 other inventions not presently claimed, but which may be claimed in future.

Claims

1. An apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face.
2. An apparatus according to claim 1 wherein, in cross-section, the internal angle between the top face and each of the side faces is around 120 degrees.
3. An apparatus according to claim 1 or claim 2 wherein the teeth on the first and second surfaces are shaped as half of a hexagon in cross-section.
4. An apparatus according to any preceding claim wherein at least one of the first and second members comprises a rotatable roller.
5. An apparatus according to any preceding claim wherein at least one of the first and second members comprises a continuous belt.
6. An apparatus according to any preceding claim wherein the first member is moveable towards and away from the second member to alter the degree of meshing engagement between the toothed surfaces of the first and second members.
7. An apparatus according to any preceding claim wherein the surface of at least one of the first and second members is adapted to reduce the friction between said surface and the sheet material being corrugated as the sheet material is deformed between the first and second members.
8. An apparatus according to claim 7 wherein the surface of at least one of the first and second members includes a friction-reducing coating.

- 5 9. An apparatus according to claim 7 wherein the surface of at least one of the first and second members includes a plurality of apertures therein and the apparatus is provided with a source of compressed air fluidly connected to said surface to deliver compressed air through the apertures to create an air cushion between said surface and the sheet material.
- 10 10. An apparatus according to claim 7 wherein the surface of at least one of the first and second members includes a plurality of roller elements on the teeth to assist the sheet material to move over the surface of said teeth.
- 11 11. An apparatus according to claim 10, wherein the roller elements are disposed along the tooth edges where the top face meets at least one of the side faces.
- 15 12. An apparatus according to any preceding claim wherein at least one of the first and second members is configured to further promote deformation of a sheet material as the sheet material is passed between the first and second surfaces.
- 20 13. An apparatus according to claim 12 wherein the surface of at least one of the first and second members includes a plurality of apertures therein and the apparatus is provided with a source of steam fluidly connected said surface to deliver steam through the apertures to the sheet material.
- 25 14. An apparatus according to claim 12 wherein the surface of at least one of the first and second members includes a plurality of apertures therein and the apparatus is provided with a vacuum source fluidly connected said surface to apply a vacuum to the air holes to draw the sheet material against said surface.
- 30 15. An apparatus according to claim 12 wherein the teeth on at least one of the first and second members includes one or more blades projecting therefrom configured to score a sheet material at intended fold lines as it is fed between the first and second members.
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16. An apparatus according to claim 15 wherein the blades are disposed where the top face meets at least one of the side faces of the respective teeth.
- 5 17. An apparatus according to any preceding claim further comprising a steam source configured to apply steam to a sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation.
- 10 18. An apparatus according to any preceding claim further comprising a heat source configured to heat a sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation.
- 15 19. An apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the surface of at least one of the first and second members is adapted to reduce the friction between said surface and the sheet material being corrugated as the sheet material is deformed between the first and second members.
- 20 20. An apparatus according to claim 19, further comprising the features of any of claims 8 to 10.
- 25 21. An apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the surface of at least one of the first and second members includes a plurality of apertures therein and the apparatus is provided with a source of steam fluidly connected said surface
- 30 35

to deliver steam through the apertures to the sheet material.

22. An apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the surface of at least one of the first and second members includes a plurality of apertures therein and the apparatus is provided with a vacuum source fluidly connected said surface to apply a vacuum to the air holes to draw the sheet material against said surface.
23. An apparatus for corrugating a continuous sheet material comprising first and second members having toothed surfaces in meshing engagement such that a planar sheet material may be fed between the first and second surfaces and shaped into a corrugated configuration by, and corresponding to, the meshing teeth, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the teeth on at least one of the first and second members includes one or more blades projecting therefrom configured to score a sheet material at intended fold lines as it is fed between the first and second members.
24. An apparatus according to any of claims 19 to 23, further comprising the features of any of claims 2 to 6, 17 and 18.
25. A method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the sheet material is deformed into a corrugated configuration by, and corresponding to, the meshing teeth.

26. A method according to claim 25 wherein the corrugations formed in the sheet material are shaped as half of a hexagon in cross-section.
- 5 27. A method according to claim 25 or claim 26 comprising moving the first member towards and away from the second member to alter the contact force with which the surface of the first member meshes with the surface of the second member.
- 10 28. A method according to claim 27 wherein the first and second members comprise rotatable rollers, the method comprising moving the first member towards the second member as each successive tooth on the first member is received within a corresponding space between teeth on the second member as the first and second members rotate in meshing engagement.
- 15 29. A method according to any of claims 25 – 28 comprising applying a vacuum through apertures in the surface of one of the first and second members to draw the sheet material against said surface.
- 20 30. A method according to claim 29 comprising applying the vacuum to draw the sheet material against said surface prior to deforming the sheet material between the first and second members.
- 25 31. A method according to any of claims 25 – 30 comprising providing compressed air through apertures in the surface of one of the first and second members to create an air cushion between said surface and the sheet material to reduce the friction therebetween as the sheet material is being corrugated.
- 30 32. A method according to any of claims 25 – 31 comprising providing roller elements on the teeth on the surface of at least one of the first and second members to assist the sheet material to move over the surface of said teeth.
- 35 33. A method according to claim 32 wherein the roller elements are provided where the top face meets at least one of the side faces of the respective teeth.

34. A method according to any of claims 25 – 33 comprising applying steam to the sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation.
- 5 35. A method according to claim 35 wherein the steam is delivered to the sheet material through a plurality of apertures in the surface of at least one of the first and second members.
- 10 36. A method according to any of claims 25 – 35 comprising heating the sheet material before or during passage between the first and second member to promote the deformation of the sheet material to a corrugated formation.
- 15 37. A method according to any of claims 25 – 36 comprising scoring the sheet material at intended fold lines as it is fed between the first and second members using blades projecting from the teeth on at least one of the first and second members.
- 20 38. A method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the sheet material is deformed into a corrugated configuration by, and corresponding to, the meshing teeth, the method comprising applying steam to the sheet material before or during passage between the first and second members to promote the deformation of the sheet material to a corrugated formation and wherein the steam is delivered to the sheet material through a plurality of apertures in the surface of at least one of the first and second members.
- 25 39. A method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the sheet material is deformed into a corrugated configuration by, and corresponding to, the meshing teeth, the
- 30 35

method comprising applying a vacuum through apertures in the surface of one of the first and second members to draw the sheet material against said surface.

- 5 40. A method of corrugating a continuous sheet material comprising feeding the sheet material between first and second members having toothed surfaces in meshing engagement, wherein the teeth on the first and second members each comprise a top face and opposing side faces, and edges where the side faces meet the top face, and wherein the sheet material is deformed into a
- 10 corrugated configuration by, and corresponding to, the meshing teeth, the method comprising scoring the sheet material at intended fold lines as it is fed between the first and second members using blades projecting from the teeth on at least one of the first and second members.
- 15 41. A method according to any of claims 38 to 40, further comprising any of the features of claims 26 to 28 and claim 36.

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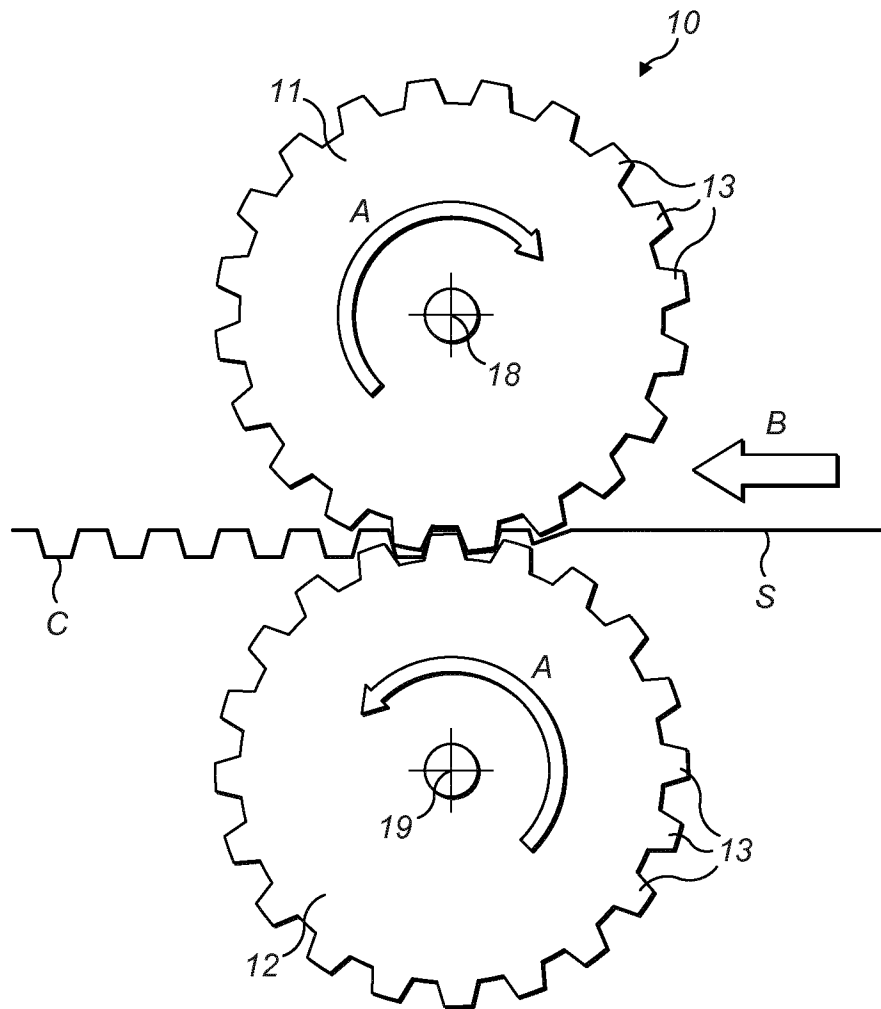


FIG. 1

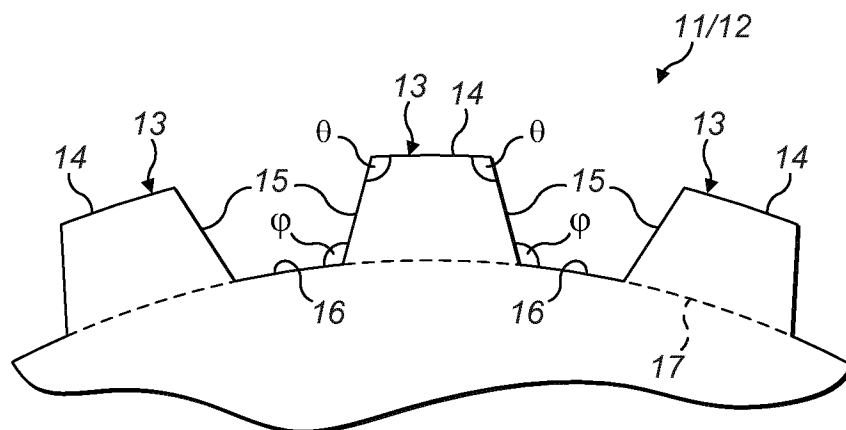


FIG. 2

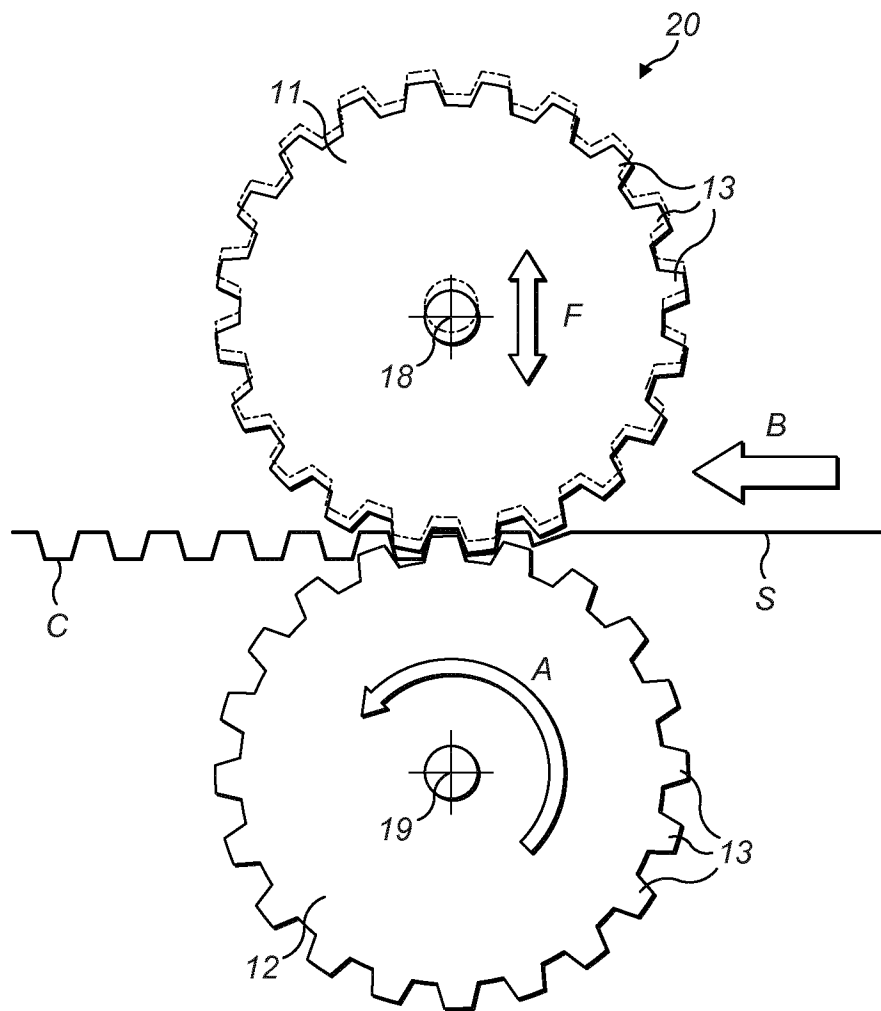


FIG. 3

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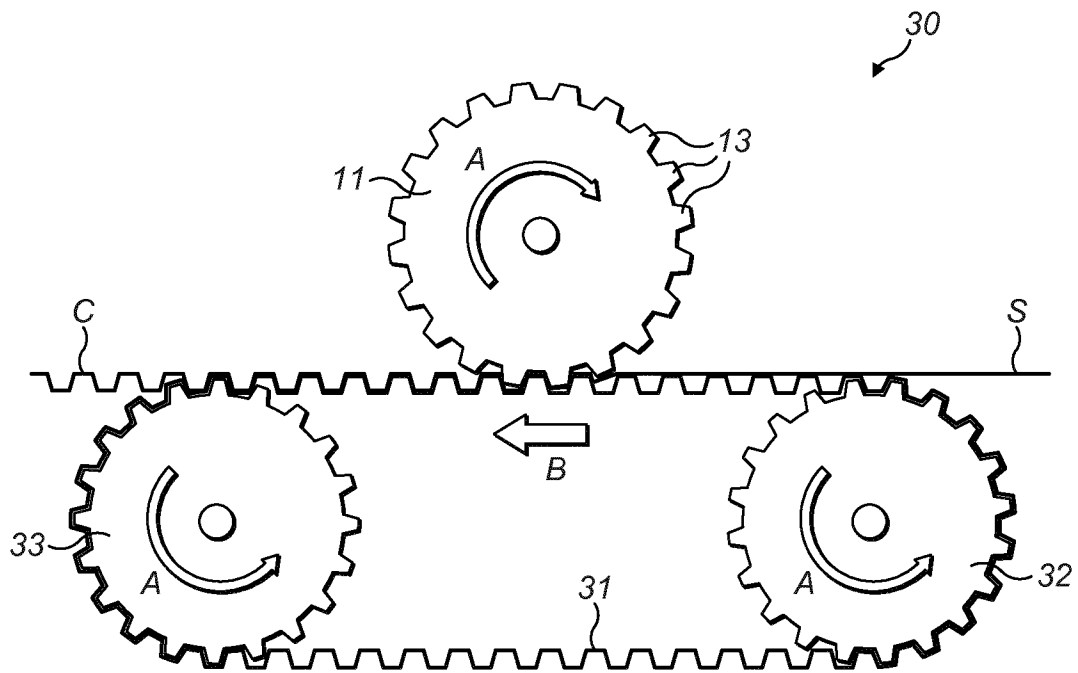


FIG. 4

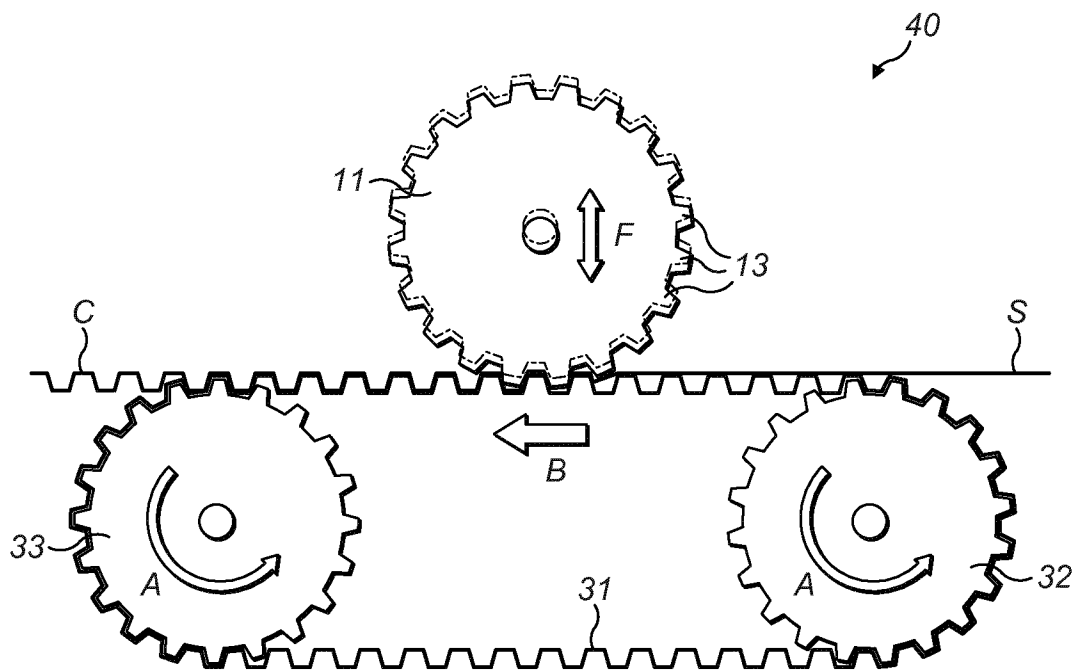


FIG. 5

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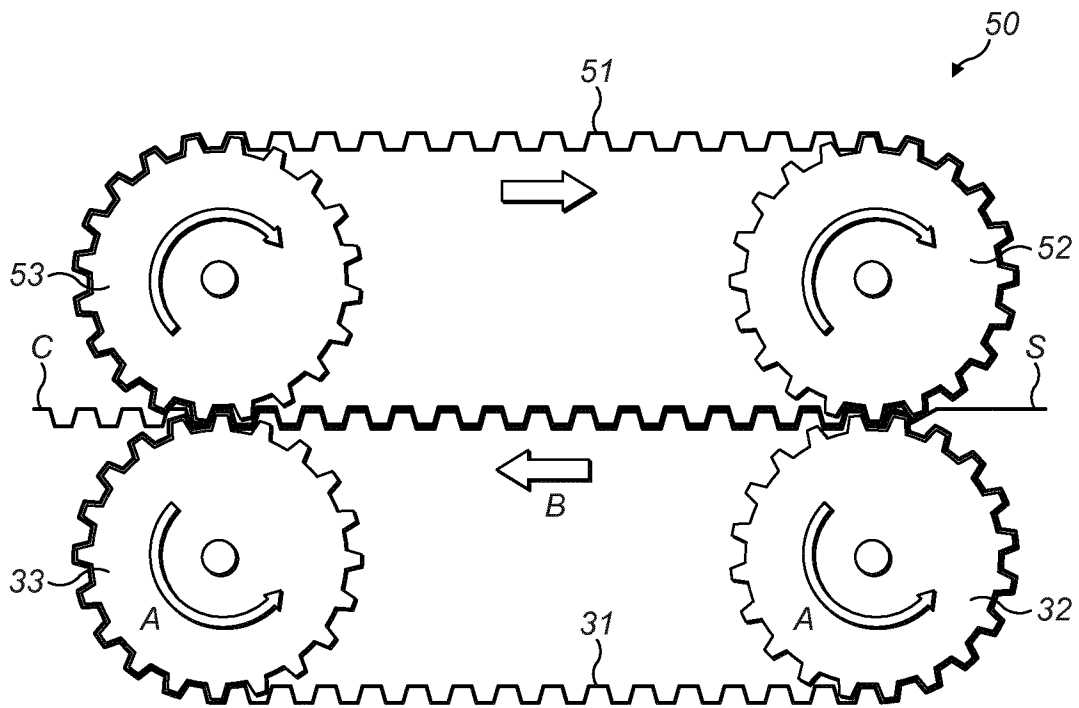


FIG. 6

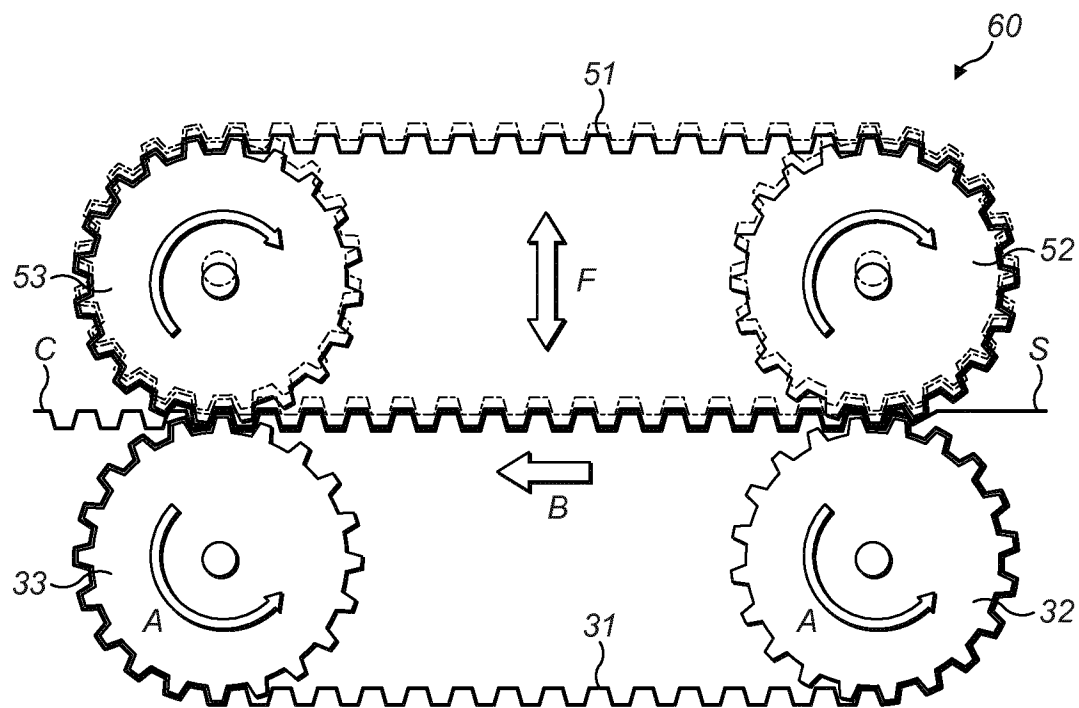


FIG. 7

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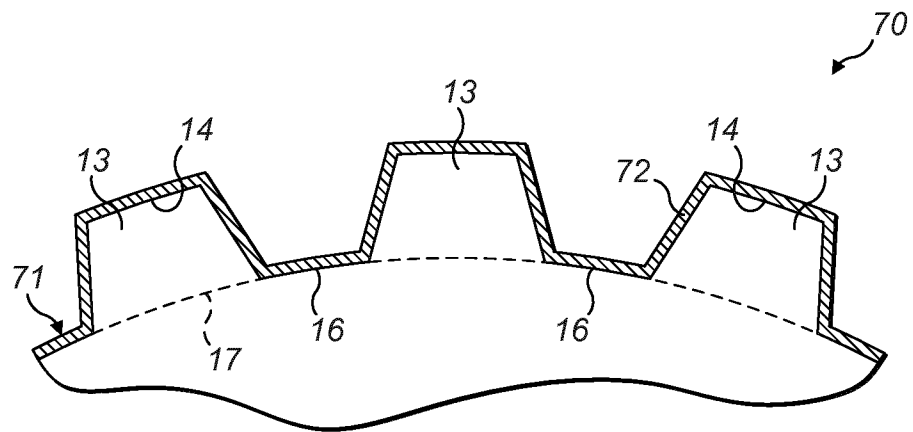


FIG. 8

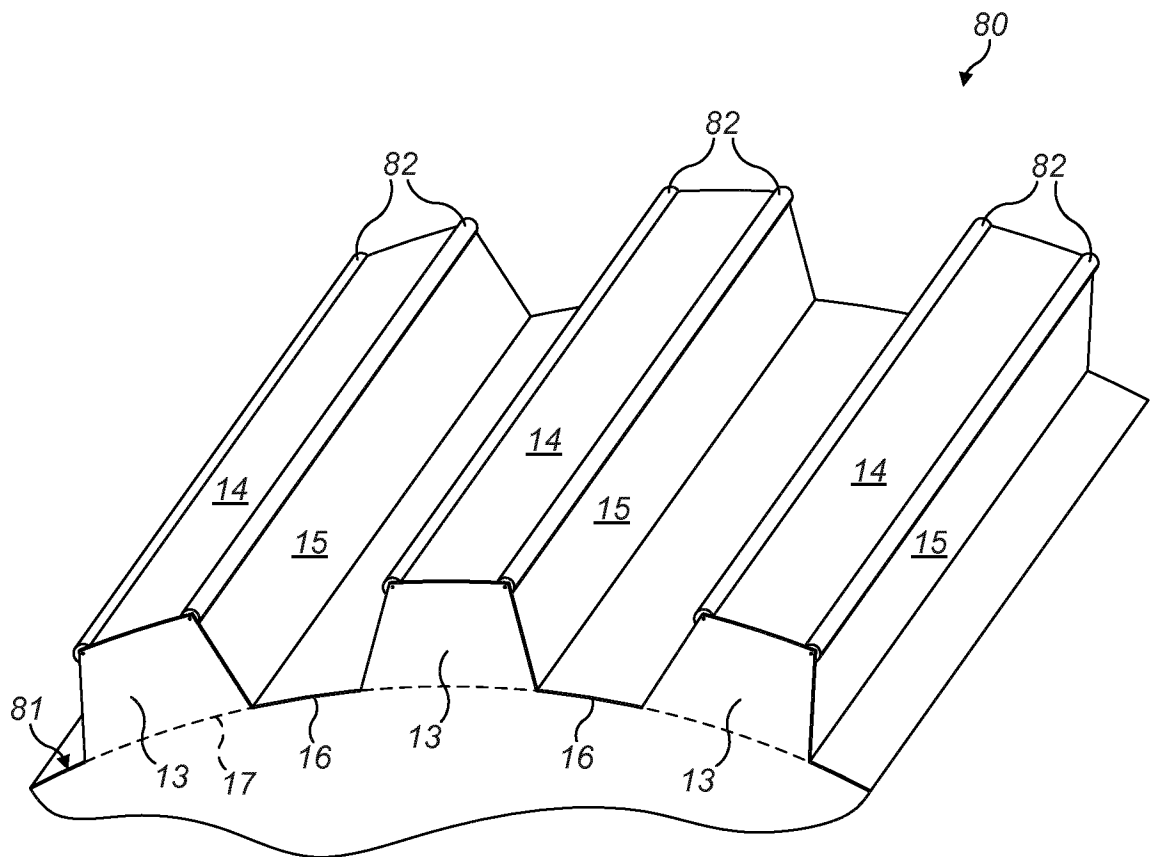


FIG. 9

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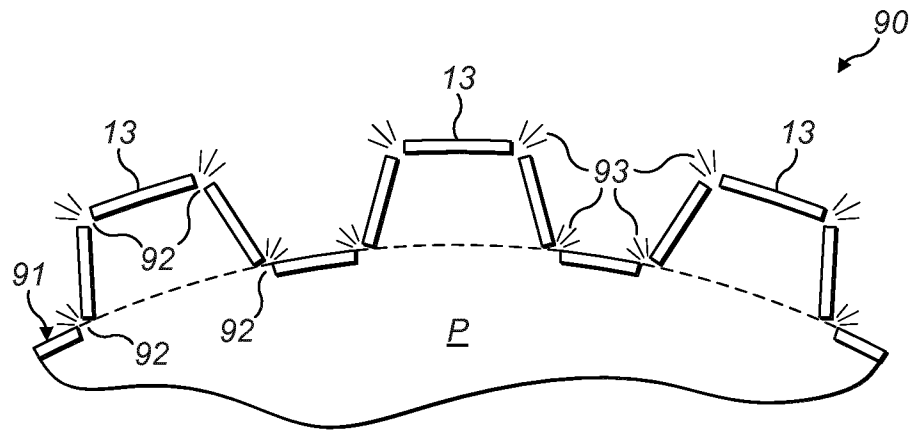


FIG. 10

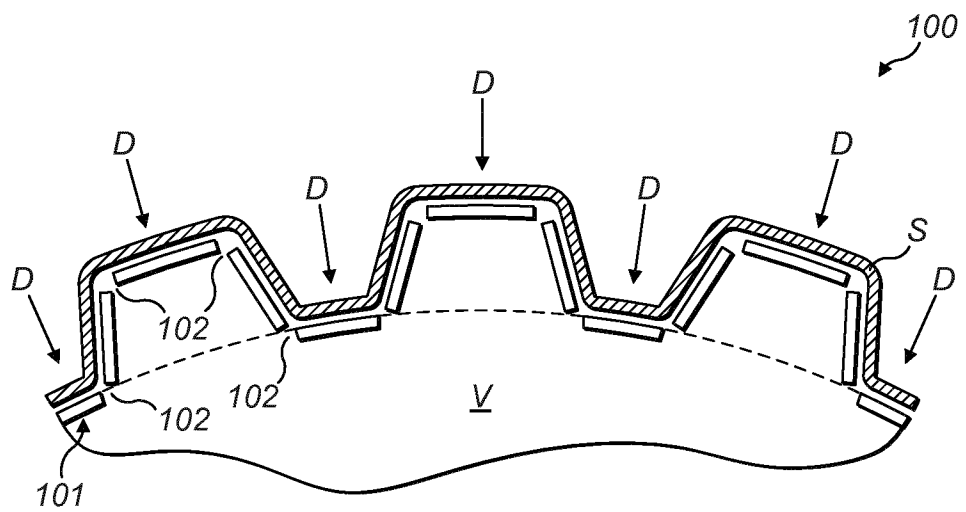


FIG. 11

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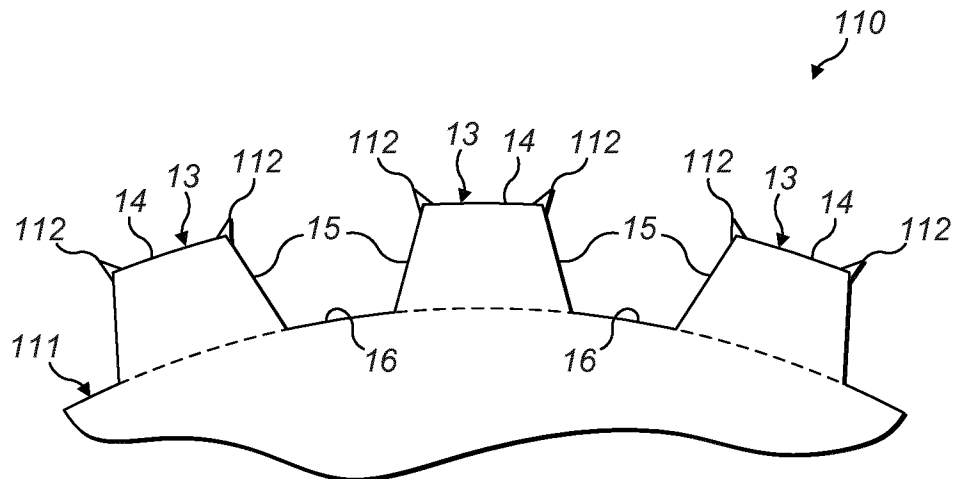


FIG. 12

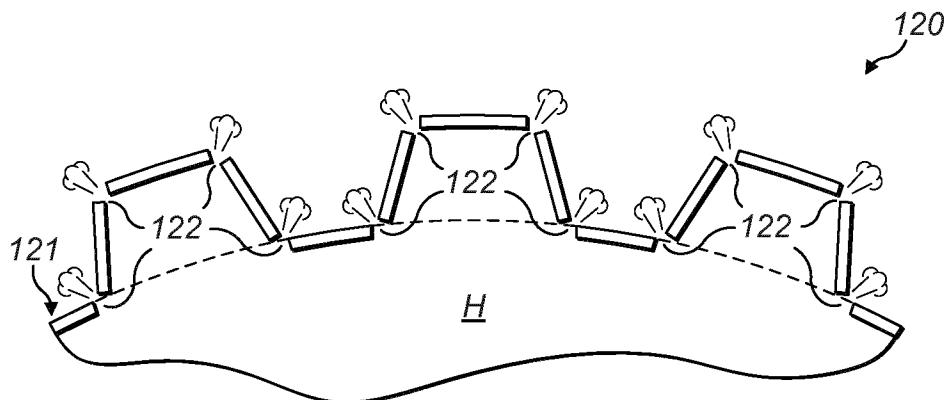


FIG. 13

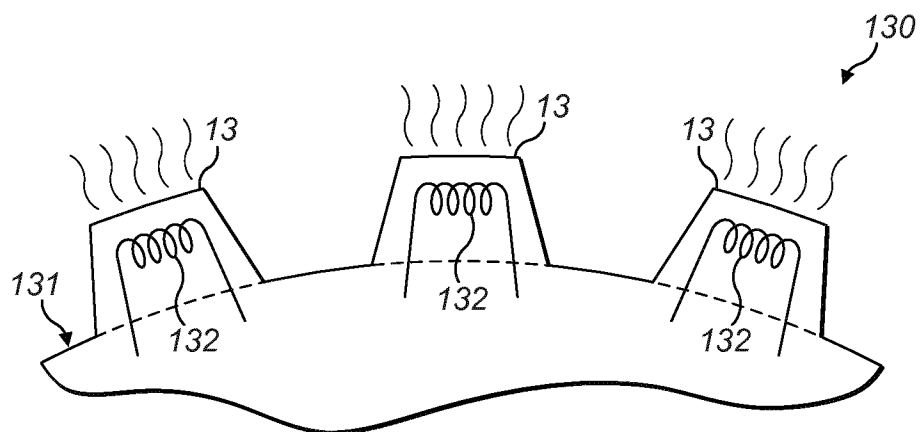


FIG. 14