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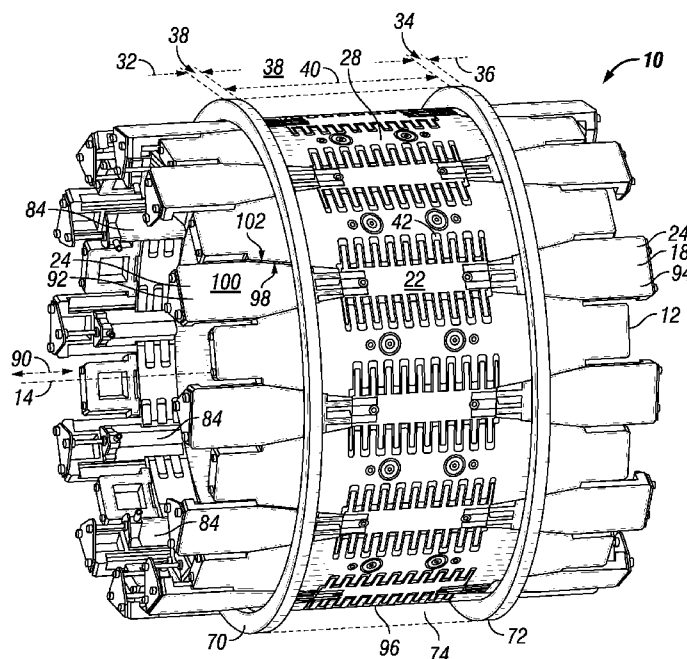


FIG. 10

(57) Abstract: An adjustable form is provided for building tire components of different sizes. The form includes a series of fixed length form elements intermittently disposed between a series of adjustable length form elements about the circumference of the form. The elements are movable to a first radius to form a first form surface that features first, second and third build regions onto which a tire could be constructed. Gaps, if any are present, in the first and second build regions are smaller than those in the axially intermediate second build region. The elements are movable to a second radius to form a second form surface with fourth, fifth, and sixth build regions for the construction of a tire of a different diameter. Gaps, if any are present, in the fourth and fifth build regions are smaller than those in the axially intermediate sixth build region.



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TITLE

ADJUSTABLE FORM FOR NON-PNEUMATIC TIRE CONSTRUCTION

FIELD OF THE INVENTION

[0001] The present invention relates generally to an adjustable form used to build a non-pneumatic tire. More particularly, the present application involves an adjustable form that can be configured to different diameters, to allow non-pneumatic tires of different sizes to be built thereon, that features both gapless build areas and gapped build areas that are strategically positioned across the adjustable form.

BACKGROUND

[0002] The production of tires may be accomplished by taking a round form, that resembles a drum, and placing strips of material thereon. The strips can be placed down onto the outer surface of the form about its entire circumference. These strips of material may be continued to be laid onto the drum and then onto themselves as they are built up into a desired tire profile. The forces used to apply the material onto the surface of the form, and subsequently onto other strips of the material already placed into position, are great. The strips of material are not rigid, and have some degree of flexibility. The form is capable of being expanded and contracted in the radial direction so that its diameter can be increased and decreased. Once the tire is constructed onto the form, the diameter of the form can be collapsed to allow the formed tire to be removed from the form.

[0003] Due to the fact that the diameter of the form can expand and contract, gaps in the surface of the form are present when the form is in the expanded diameter state. This adjustable diameter drum may allow for tires of different diameters to be built thereon. These gaps are required because metal, or other surface forming material, itself does not expand but rather the individual sections making up the individual portions of the surface are moved radially. The presence of gaps in the surface may allow for the material that is placed thereon to be forced into the gaps due to the large amount of force applied during the building process. Material placed into the gaps will cause non-uniformity and will cause the tire to be scrapped.

[0004] One way to avoid gaps when building tires of different diameters onto drums is to use a different diameter drum for the building of tires of different diameters. This technique is time consuming because when one desires a different sized tire to be produced, the entire drum, or at least the forming surface, has to be removed and replaced with one of the desired diameter. Additional cost and time will be required to build tires in this manner. Another way of eliminating gaps in the form surface is to construct the form out of a geometry of tapered sections that face one another. As the sections expand from the axial center of the form to thus expand the diameter of the form, the sections move in the axial direction simultaneously in order to maintain a gapless center section surface of the form. Although capable of maintaining a gapless center section, this type of form is complex and requires segments with tight tolerances and interlocking segments, and limits the form surface to a center area that necessarily shrinks in width as the form increases in diameter. Although ways of building tires of different diameters onto forms exist, there remains room for variation and improvement within the art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth more particularly in the remainder of the specification, which makes reference to the appended Figs. in which:

[0006] Fig. 1 is a side view of an adjustable form in a tire removal orientation.

[0007] Fig. 2 is a perspective view of a fixed length form element.

[0008] Fig. 3 is a perspective view of an adjustable length form element.

[0009] Fig. 4 is a top view of a movable component of the adjustable length form element.

[0010] Fig. 5 is a side view of the movable component of Fig. 4.

[0011] Fig. 6 is a top view of the adjustable length form element engaged with two fixed length form elements in the tire removal orientation of the adjustable form.

[0012] Fig. 7 is a side view of the adjustable form in a first form surface orientation.

[0013] Fig. 8 is a top view of the adjustable length form element engaged with two fixed length form elements in the first form surface orientation.

[0014] Fig. 9 is a cross-sectional view along line 9-9 of Fig. 8 of the adjustable form in the first form surface orientation with a first non-pneumatic tire built upon the first form surface.

[0015] Fig. 10 is a perspective view of the adjustable form in the first form surface orientation.

[0016] Fig. 11 is a front view of a portion of the adjustable form in the first form surface orientation showing gaps between the fixed length form element and the adjustable length form element.

[0017] Fig. 12 is a side view of the adjustable form in a second form surface orientation.

[0018] Fig. 13 is a top view of a fixed length form element and two adjustable length form elements in the second form surface orientation.

[0019] Fig. 14 is a cross-sectional view along line 14-14 of Fig. 13 of the adjustable form in the second form surface orientation with a second non-pneumatic tire built upon the second form surface.

[0020] Fig. 15 is a perspective view of the adjustable form in the second form surface orientation.

[0021] Fig. 16 is a top view of the adjustable form in the first form surface orientation in accordance with a different exemplary embodiment.

[0022] Fig. 17 is a top view of the adjustable form in the second form surface orientation in accordance with a different exemplary embodiment.

[0023] Fig. 18 is a side view in partial cross-section of a movable component made of a pair of blocks.

[0024] Fig. 19 is the side view in partial cross-section of Fig. 18 with the lower block moved in order to pull the upper block in a radial direction and axial direction of the adjustable form.

[0025] Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the invention.

DETAILED DESCRIPTION OF REPRESENTATIVE EMBODIMENTS

[0026] Reference will now be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, and not meant as a limitation of the invention. For example, features illustrated or described as part of one embodiment can be used with another embodiment

to yield still a third embodiment. It is intended that the present invention include these and other modifications and variations.

[0027] It is to be understood that the ranges mentioned herein include all ranges located within the prescribed range. As such, all ranges mentioned herein include all sub-ranges included in the mentioned ranges. For instance, a range from 100-200 also includes ranges from 110-150, 170-190, and 153-162. Further, all limits mentioned herein include all other limits included in the mentioned limits. For instance, a limit of up to 7 also includes a limit of up to 5, up to 3, and up to 4.5.

[0028] An adjustable form 10 is provided that expands and contracts in the radial direction 16 in order to allow a first non-pneumatic tire 66 and a second non-pneumatic tire 76 to be built thereon that have different diameters from one another. The adjustable form 10 assumes a first form surface orientation in which certain axial lengths of the first form surface 28 have no gaps or have very small gaps to allow sidewalls 70, 72 of the first tire 66 to be built thereon. The first form surface 28 includes other regions along an axial length that does have gaps 42 onto which other portions of the first tire 66 are built. However, these other portions of the first tire 66 are stiffer and can tolerate being built upon a surface that includes the gaps 42. The adjustable form 10 can expand in the radial direction 16 to a second form surface orientation to form a second form surface 48 onto which a second non-pneumatic tire 76 can be built. The second form surface 48 features axial lengths that include no gaps or that include extremely small gaps so that sidewalls 80, 82 of the second tire 76 can be built thereon. The second form surface 48 likewise features axial lengths that do in fact include gaps 62 over which portions of the second tire 76 are built. However, these portions of the second tire 76 are stiffer than the sidewall portions 80, 82 and thus will not deflect into the gaps 62 during construction of the second tire 76. The adjustable form 10 can collapse into a smaller radius to allow the tires 66, 76 to be removed therefrom. As such, the adjustable form 10 allows for tires of different diameters to be built thereon through radial expansion/contraction of the adjustable form 10, and makes use of the fact that the tires built thereon have a specific architecture that does not require gapless surfaces at all points of construction of the tires, but only at some specific locations.

[0029] Fig. 1 is a side view of the adjustable form 10 in a tire removal orientation in which the diameter of the adjustable form 10 is smaller than that of other orientations. The adjustable form 10 is made from a plurality of fixed length form elements 12 alternatingly

disposed between a plurality of adjustable length form elements 18 so that the elements 12 and 18 alternate with one another completely around the circumference 20 of the adjustable form 10. As shown, eight fixed length form elements 12 are present, and eight adjustable length form elements 18 are present. However, in other embodiments, from 9-12, from 13-20, or up to 50 fixed and adjustable length form elements 12, 18 are included in the adjustable form 10. The form elements 12, 18 define an upper surface that extends about the circumference 20 of the adjustable form 10 and is spaced from a form axis 14 in the radial direction 16. Although not shown, mechanisms for moving the form elements 12, 18 in the radial direction 16 can be included as well, and these types of mechanisms are known.

[0030] Fig. 2 shows an embodiment of the fixed length form element 12 that includes a series of teeth that are linearly arranged in the axial direction 90. The fixed length form element 12 has an upper surface 96 that extends across the entire axial length of the fixed length form element 12. A pair of tapers 98 are located on opposite sides of the teeth section of the fixed length form elements 12 in the axial direction 90. A block or other element can be located below the upper surface 96 that can be used to mount the upper surface 96 to the radially expandable/movable sections of the adjustable form 10. The tapers 98 do not move relative to other portions of the fixed length form elements 12 when the fixed length form elements 12 are moved in the radial direction 16.

[0031] Fig. 3 shows the adjustable length form element 18 that has a center component 22 that includes a series of teeth that extend in the axial direction 90. The center component 22 can be mounted via a block onto the radially movable components of the adjustable form 10. The center component 22 and a pair of movable components 24 define the upper surface of the adjustable length form element 18. The center component 22 is located between the movable component 92 and the movable component 94 in the axial direction 90. The movable components 92, 94 are movable in the axial direction 90 relative to the center component 22. Air cylinders 84 are present in order to move the movable components 92, 94 in the axial direction 90. However, other mechanisms of moving the movable components 24 in the axial direction 90 are possible such as hydraulic cylinders, mechanical mechanisms, or magnets. The air cylinder 86 can be actuated in order to move the movable component 92 in the axial direction 90 relative to the center component 22. The air cylinder 86 can be mounted to a block that is rigidly attached to and does not move relative to the center component 22, and a pin or slide engagement

between the center component 22 and the movable component 92 is provided in order to allow these parts to move relative to one another in the axial direction 90. The movable component 94 can be arranged in a similar manner as it is actuated by the air cylinder 88 and urged to move in the axial direction 90 relative to the center component 22. The movable components 92, 94 can be moved simultaneously with one another so that they both move together at the same time in the axial direction 90. In this regard, they 92, 94 may both move away from one another or towards one another. In other arrangements, the movable components 92, 94 can be individually actuated so that one moves in the axial direction 90 while the other does not move, or so that both 92, 94 move in the same direction as one another in the axial direction 90. The movable components 24, 92, 94 move independently of the mechanism that causes movement of the adjustable form 10 in the radial direction 16.

[0032] Figs. 4 and 5 show top and side views of one of the movable components 94 of the plurality of movable components 24 of the adjustable length form elements 18. The movable component 94 has an upper surface 100 onto which the tires 66, 76 can be built. The movable component 94 has a pair of tapers 102 that extend both in the axial direction 90 and in the circumferential direction of the adjustable form 10. The portions of the upper surface 100 outward in the axial direction 90 are not tapered. The angle between the taper 102 and the portion of the upper surface 100 outward in the axial direction 90 that is not tapered can be 7.5 degrees in one embodiment. The tapers 102 can extend in the radial direction 16 some depth into the movable component 94 so that an inner surface of the movable component 94 is likewise tapered. The tapers 102 are oriented so that they are reversed from, and also directly face, the tapers 98.

[0033] Fig. 6 illustrates a portion of the outer surface of the outer surface of the adjustable form 10 in the tire removal orientation of the adjustable form 10. The arrangement between two of the fixed length form elements 12 and one of the adjustable length form elements 18 is shown, but it is to be understood that this arrangement repeats itself along the entire outer surface of the adjustable form 10 about its circumference 20, and that only one section of the design needs to be described as its description would be repetitive about the entire adjustable form. The center component 22 includes teeth that intermesh with teeth of the two adjacent fixed length form elements 12. The teeth may be engaged to one another to such an extent that no gaps are present between the teeth in the tire removal orientation. The movable components

24 may be expanded in the axial direction 90 so that they 24 are farthest from the center component 22 in the axial direction 90. This arrangement causes gaps to be present between the movable components 92, 94 and the fixed length form elements 12. Portions of the upper surface 100 may extend beyond the upper surface 96 in the axial direction 90. The tapers 98 of the upper surface 96 of the fixed length form elements 12 may directly face but not engage the tapers 102 of the upper surface 100 of the movable components 24. Gaps may thus be present between the tapers 98 and 102 such that no portion of the movable components 24 engage the fixed length form elements 12.

[0034] When it is desired to build a first tire 66 onto the adjustable form 10, the adjustable form 10 is expanded from the tire removal orientation of Fig. 1 to the first form surface orientation of Fig. 7. To do this, any type of mechanism may be employed to expand the components 12, 18 in the radial direction 16. Once expanded into the first form surface orientation of Fig. 7, the circumference 20 of the first form surface 28 is greater than the circumference 20 of the outer surface of the adjustable form when in the tire removal orientation. The first form surface 28 has a first radius 26 that is the same about the form axis 14. The first form surface 28 thus has a first diameter 108 that is twice that of the first radius 26. The first diameter 108 is selected so that it corresponds to the diameter of the first non-pneumatic tire 66 that is to be constructed onto the adjustable form 10.

[0035] Fig. 8 shows one of the adjustable length form elements 18 and two of the fixed length form elements 12 of the adjustable form 10 that make up the first form surface 28. It is to be understood that the same arrangement is present around the entire circumference 20. As the elements 12, 18 expand in the radial direction 16 from that of the tire removal orientation, gaps 42 will develop between the teeth of the center component 22 and the fixed length form elements 12. This is because the area of the first form surface 28 is greater than the area of the outer surface when in the tire removal orientation. Additionally, the movable components 24 are moved some amount towards the center component 22 in the axial direction 90. However, the movable components 24 are not moved their entire range in the axial direction 90, but are only moved some portion of their range in the axial direction 90 when transitioning from the tire removal orientation to the first form surface 28 orientation. This movement causes an engagement between the tapers 102 and 98 so that the movable components 24 engage the fixed length form elements 12. Depending upon the geometry of the components 12, 18 gaps may still

be present between the movable components 24 and the fixed length form elements 12 when defining the first form surface 28.

[0036] The first form surface 28 has an axial midpoint 112, and the movable components 24 may be positioned the same distance from the axial midpoint 112 in the axial direction 90 when in their orientations forming the first form surface 28. The first form surface 28 may be broken up into three different regions. A first build region 30 may be defined by the fixed length form elements 12 and the movable components 24, 92. The tapered sections of the fixed length form elements 12 and the movable components 24 can be present in the first build region 30, and the first build region 30 may extend along a first axial length 32 of the first form surface 28. The movable components 24, 92 and the fixed length form elements 12 can engage one another so that a gap is not present between them in the first build region 30. This engagement may take place along the entire circumference 20 between the various movable components 24, 92 and the fixed length form elements 12 so that no gaps are present in the first build region 30 around the entire circumference 20.

[0037] The first form surface 28 also has a second build region 34 that is spaced from the first build region 32 in the axial direction 90, and that is located the same distance from axial midpoint 112 as the first form surface 28 in the axial direction 90. The second build region 34 of the first form surface 28 is defined by the movable component 24, 94 and the fixed length form elements 12, and this pattern repeats along the entire circumference 20 of the first form surface 28. The tapered surfaces of the movable components 24, 94 engage the tapered surfaces of the fixed length form elements 12, and no gaps are present in the second build region 34 between these members. As such, no gaps may be present in the entire second build region 34 along the entire circumference of the second build region 34. The second build region 34 has a second axial length 36 that may be the same length as the first axial length 32 in the axial direction 90.

[0038] A third build region 38 is present between the first build region 30 and the second build region 34 and borders both the first and second build regions 30, 34. The third build region 38 thus extends from the first build region 30 to the second build region 34. The third build region 38 has a third axial length 40 that is greater than the first axial length 32, and that is greater than the second axial length 36. The third build region 38 is composed of the center component 22, the fixed length form element 12, and may likewise include portions of the movable components 92, 94 that are portions of these components 92, 94 closest to the axial

midpoint 112 in the axial direction 90. The third build region 38 also includes gaps 42 in the surface forming the third build region 38, and the gaps 42 are present between the teeth of the center component 22 and the fixed length form elements 12.

[0039] Fig. 9 shows the adjustable form 10 defining the first form surface 28 in cross-sectional view with the first tire 66 built thereon. The first tire 66 is a non-pneumatic tire and the section of the first tire 66 shown being built upon the first form surface 28 is a shear band 68. Layers of tissue that can include rubber, nylon, plastic, or other components are wrapped around the entire circumference 20 of the first form surface 28. These strips may be small strips measuring 1 millimeter in thickness and 22 millimeters in width, or smaller, and can be made of different types of material thus forming different types of tissues within the first tire 66 to make up the first tire 66. The sidewall 70 of the first tire 66 that is a portion of the shear band 68 can be made of tissue that is relatively soft. There is an extremely large force pushing upon the tissue of the sidewall 70 and this large laying force may cause the tissue making up the sidewall 70 to be pressed into gaps present on the first form surface 28. The force pushing onto the tissue making up the tire 66 during its build may be 800 Newtons normal to the surface onto which the material of the tissue is laid. The sidewall 70 is built upon the first form surface 28 that within the first build region 30, and because the first build region 30 lacks gaps in the surface of the adjustable form 10 the tissue making up the sidewall 70 will not be pressed into any gaps and will be correctly built and incorporated into the shear band 68 making up the sidewall 70.

[0040] The tissue making up the other sidewall 72 may likewise be of a softness, flexibility, that it too will be pushed into gaps within the surface of the adjustable form 10 onto which it is built by the forces exerted thereon through the building process. The sidewall 72 is built within the second build region 34, and as previously described the second build region 34 does not have any gaps. The flexible, compliant material making up the sidewall 72 will not be pressed into the adjustable form 10 but will instead be built upon its upper surface and correctly incorporated into the shape making up the sidewall 72.

[0041] The shear band 78 includes belt tissue 74 between the sidewalls 70, 72. The belt tissue 74 is more rigid than the material making up the sidewalls 70, 72. The strips making up the belt tissue 74 can be laid down upon the first form surface 28 in the third build region 38. Forces imparted onto the belt tissue 74, when forming the sections of the shear band 68, are not strong enough to push the belt tissue 74 into any gaps present on the first form surface 28

because of the rigidity of the belt tissue 74. As shown, gaps 42 are in fact present on the first form surface 28 in the third build region 38, and the gaps 42 exists when the belt tissue 74 is placed onto the first form surface 28 and the components of the shear band 68 are built. The strips making up the belt tissue 74 can be small strips 1 mm or less in size and can be wound around the entire circumference 20 of the first form surface 28 in the third build region 38 but due to the rigidity of the material making up the belt tissue 74 are not pressed into the gaps 42. As such, the adjustable form 10 may be designed so that gaps are present in its surface when building a tire at locations in which the material of the first tire 66 are strong, and in areas into which softer materials are used no gaps are present so that these softer materials can be formed on a solid surface without being pushed into the adjustable form 10. The material making up the belt tissue 74 may be rigid enough so that the area needed to be gapless is reduced to only two small bands on either side of the belt tissue 74.

[0042] Fig. 10 shows the adjustable form 10 in the configuration that forms the first form surface 28 in perspective view. The movable components 92, 94 extend axially outboard from the adjacent fixed length form elements 12 so that they are in fact located outboard in the axial direction 90. The air cylinders 84 are located inward from the first form surface 28 in the radial direction 16, and engage plates that are in turn attached to the movable components 92, 94 to move the plates to in turn cause the movable components 92, 94 to move in the axial direction 90 relative to the center components 22 and the fixed length form elements 12. Fig. 11 is a close up view of the adjustable form 10 in the first form surface 28 orientation. The center component 22 and the fixed length form elements 12 are shown, and gaps 42 are present between interlocking teeth of the center component 22 and the fixed length form element 12. This area of the adjustable form 10 is the third build region 38, and the portions of the first tire 66 built upon the third build region 38 are strong, rigid enough to withstand being pressed into the gaps 42 so that all parts of the first tire 66 built on the third build region 38 are on the first form surface 28 and none are located closer to the form axis 14 in the radial direction 16 than the first form surface 28.

[0043] The adjustable form 10 can be adjusted in order to build tires of different diameters thereon. The diameter of the adjustable form 10 can be increased from that of the diameter 108 of the first form surface 28 to a diameter 110 of a second form surface 48. The adjustable form 10 arranged into the second form surface 48 is shown with reference to Fig. 12.

The diameter 110 is larger than diameter 108 so that a second tire 76 that has a greater diameter than the first tire 66 can be built onto the same adjustable form 10. The second radius 46 is greater than the first radius 26, and is greater than the radius of the adjustable form 10 when in the tire removal orientation. The number of fixed length form elements 12 and adjustable length form elements 18 remain the same as in the first form surface 28 orientation and in the tire removal orientation, but they are moved outward in the radial direction 16 from these other orientations to achieve the second form surface 48 orientation. The circumference 20 of the second form surface 48 is thus larger than the circumference of the first form surface 28 orientation and the tire removal orientation, and gaps formed by the separation of the fixed length form elements 12 and the adjustable length form elements 18 will be larger.

[0044] Fig. 13 shows the second form surface 48 in which the movable components 24 are both moved closer to the axial midpoint 114 of the second form surface 48 in the axial direction 90. This axial movement, along with the radial expansion of the outer surfaces, causes the movable components 24 to engage the fixed length form elements 12 at different locations than in the first form surface 28 orientation. A fourth build region 50 is formed that extends completely around the circumference of the second form surface 48. The fourth build region 50 extends a fourth axial length 52 across the second form surface 28 and does not have any gaps present thereon. As such, the movable component 92 engages the two adjacent fixed length form elements 12 at the fourth build region 50 to form a solid surface completely around the circumference 20 at the fourth build region 50. Spaced from the fourth build region 50 in the axial direction 90 is a fifth build region 54 that extends a fifth axial length 56 and that also extends around the circumference 20. The movable component 94 engages the fixed length form elements 12 so that gaps are not present at any portion of the fifth build region 54.

[0045] A sixth build region 58 borders both, and is present between, the fourth and fifth build regions 50, 54. The sixth build region 58 has a sixth axial length 60 that is longer than the fourth axial length 52, and is longer than the fifth axial length 56. Due to the radial expansion of the adjustable form 10 from the first form surface 28 to achieve the second form surface 48, the gaps 62 present in the sixth build region 58 are larger than the gaps 42 in the third build region 38. The movable components 92, 94 are moved in the axial direction 90 inboard towards the axial midpoint 114 to such an extent that the movable components 92, 94 and the fixed length form elements 12 are located at the same distance from the axial midpoint 114 in the axial

direction 90. The movable components 92, 94 are moved as far as possible towards the axial midpoint 114 in the axial direction 90, so that they are in their most inboard extent, when in the second form surface 48 configuration.

[0046] With reference to Fig. 14, a second tire 76, with a diameter greater than the first tire 66, is built upon the adjustable form 10 when in the second form surface 48 orientation. Although the diameter 110 is greater, the width of the second tire 76, that is the length of the second tire 76 in the axial direction 90, is less than the width/length in the axial direction 90 of the first tire 66. The second tire 76 is a non-pneumatic tire, and the portion of the second tire 76 constructed on the second form surface 48 is a shear band 78 of the non-pneumatic tire. The shear band 78 includes a side wall 80 that is made of material compliant enough to be pressed into gaps in the surface onto which it is constructed. However, the side wall 80 is constructed in the fourth build region 50 that does not include any gaps, and thus the tissue making up the side wall 80 can be built thereon without fear of being pushed into any gaps present on the second form surface 48. The other side wall 82 may likewise be made of material that can compress into gaps present on the surface onto which it is constructed. The fifth build region 54 does not have any gaps, and the material built upon the surface of the fifth build region 54 may be pliable and otherwise capable of entering gaps present in the fifth build region 54.

[0047] Belt tissue 83 of the shear band 78 can be built upon the second form surface 48 in the sixth build region 58 because the belt tissue 83 may be strong enough and non-pliable enough that it is not forced into gaps 62 present in the sixth build region 58. The forces acting upon the belt tissue 83 may urge it towards the form axis 14 in the radial direction 16, but they are not strong enough to cause the belt tissue 83 to be pressed into the gaps 62. With this construction, the areas of the adjustable form 10 that require no gaps to be present can be strategically placed at appropriate areas of the surface of the adjustable form 10 to allow these sections of the non-pneumatic tire to be built, while other sections that are stiffer can be placed at portions that include gaps, but are strong enough to be prevented from being pushed into the gaps by the forces imparted onto the material. Fig. 15 shows the adjustable form 10 in the second form surface 48 orientation in which the air cylinders 84 pull the movable components 24 to their most inward position in the axial direction 90.

[0048] The adjustable form 10 has been described as being adjustable into a first form surface 28 and a second form surface 48 in which the first build region 30, second build region

34, fourth build region 50, and fifth build region 54 all lack any gaps on their surfaces so that the material making up portions of the non-pneumatic tires 66, 76 are not pressed into any gaps in these regions 30, 34, 50, 54. However, the material and the forces imparted onto the material may in some instances tolerate the presence of small gaps in the build regions 30, 34, 50, 54. For example, if the gaps were 0.1 millimeters or less in width, it may be possible to still build the sidewalls 70, 72, 80, 82 within the build regions 30, 34, 50, 54 in which gaps are in fact present. The width of the gaps that could be tolerated would be dictated by the particular material used in that instance, and by the amount of force applied to that material that would or would not cause the material to enter any gaps present. Generally, the gaps should be small as the material in the sidewalls 70, 72, 80, 82 is typically pliable to such an extent that it would be pressed into the gaps.

[0049] Fig. 16 shows the first form surface 28 of the adjustable form 10 in accordance with one exemplary embodiment in which gaps 44 are present in the first build region 30 and in the second build region 34. The gaps 44 extend all the way across the entire axial lengths 32, 36. In other embodiments, the gaps 44 may extend only part way across axial length 32, and may extend only part way across axial length 36. Although shown as also extending across the entire axial length 40 of the third build region 38, the gaps 44 may extend along only part of the axial length 36, or may not even be present in the third build region 38 in accordance with other exemplary embodiments. The gaps 44 may have a width less than the width of the gaps 42. In some instances, the gaps 44 are 0.1 millimeters or less in width. The gaps 42 can be variable in size but may be 1.0 millimeters or greater in some arrangements. As the adjustable form 10 increases in size in the radial direction 16, the gaps will likewise increase in size. The axial lengths 32, 36 may be 15 millimeters in some embodiments.

[0050] The adjustable form 10 can be expanded in the radial direction 16 to form the second form surface 48, and the movable members 24 can be moved into desired positions to form the fourth and fifth build regions 52, 54. The Fig. 17 shows the adjustable form 10 positioned into the second form surface 48 orientation in which gaps 64 are present both in the fourth and fifth build regions 52, 54. The gaps 64 extend across the entire axial lengths 52, 56, but it is to be understood that they may extend over less than the entire axial lengths 52, 56 in other embodiments. The gaps 64 may have the same width across their entire lengths, or their widths may vary at different points. Also, although shown as going across the entire axial length

60 of the sixth build region 58, the gaps 64 may be less than the entire axial length 60 or may not even be present in the sixth build region 58. The width of gaps 64 may be less than the widths of gaps 62.

[0051] The act of building a tire 66, 76 onto the adjustable form 10 can cause pressing of the material against the outer surface of the adjustable form 10 with such force that it may tend to stick against the outer surface. This sticking may make it difficult for the movable components 24 to move in the axial direction 90 as the sticking forces function to keep it held in place. Friction holding the movable component 24 in place may be overcome by applying additional force thereto by the air cylinders 84. In other arrangements a special coating can be applied to the upper surface of the movable components 24 to allow them to more easily move when force is applied such as a friction reducing coating that lowers the coefficient of friction of the engaging portions of the upper surface of the movable components 24 with the tires. Fig. 18 shows an alternative exemplary embodiment in which the movable component 24 is provided with a feature that assists it in moving in the axial direction 90 to overcome any friction preventing moving in the axial direction 90, such as the presence of a sticking force between the movable component 24 and the first tire 66. The adjustable form 10 is configured into a first form surface 28 orientation and the first tire 66 is built thereon in which the belt tissue 74 and the tissue making up the sidewall 72 both engage and function to hold the movable component 94 in place in the axial direction 90 through a sticking force. If it is desired to move the movable component 94 outboard in the axial direction 90, the sticking force will function to hold it in place.

[0052] The movable component 94 is made up of an upper block 116 and a lower block 118. The upper block 116 engages the first tire 66, and the lower lock 118 is free from engagement with the first tire 66. The air cylinder 84 is attached to the lower block 118 and is not directly attached to the upper block 116, but is instead indirectly attached to the upper block 116 through the lower block 118. The upper block 116 and lower block 118 are attached to one another via a spring 120. The upper block 116 has a sloped surface 124, and the lower block 118 has a complimentary sloped surface 122 that directly faces the sloped surface 124. The sloped surfaces 124 are sloped in that they extend both in the radial direction 16 and the axial direction 90. Fig. 18 shows the movable component 24 before actuation of the air cylinder 84 to move the movable component 24 in the axial direction 90 outboard, or to the right in Fig. 18. The sloped

surface 124 does not engage the sloped surface 122, but the surfaces 124, 122 could engage one another in other embodiments before the axial, outboard movement of the movable component 94.

[0053] Movement of the air cylinder 84 in the axial direction 90, to the right in Fig. 19, causes the lower block 118 to move in the axial direction 90 as there is no sticking of the lower block 118 to the tire 66 to prevent its movement in the axial direction 90. Movement of the lower block 118 will cause the sloped surfaces 122, 124 to engage one another. Because the sloped surface 122 of the upper block 116 has a surface normal that is directed both in the radial direction 16 and in the axial direction 90, force imparted by the sloped surface 124 of the lower block 118 onto the sloped surface 122 will likewise have a component in the axial direction 90 and in the radial direction 16 due to the fact that the sloped surface 124 also has a surface normal in the radial 16 and axial 90 directions. The force imparted onto the upper block 116 due to the sloped surfaces 122, 124 will thus have a component in the radial direction 16, and this component of force in the radial direction 16 causes the upper block 116 to be pulled in the radial direction 16 away from the tire 66, and thus downward in Fig. 19. This force, motion will cause the upper block 116 to be moved away from the tire 66 and there will be no sticking force acting on the upper block 116 because its movement is not in a direction that causes friction. The upper block 116 will thus be disengaged with the tire 66 and will also move in the axial direction 90 due to the sloped surface 122 and the fact that a component of force in the axial direction 90 is present. The movement of the upper block 116 in the radial direction 16 may be constrained through the geometry of the upper block 116 or by hitting some other component of the adjustable form 10 in the radial direction 16 below the upper block 116 in Fig. 19 that prevents further movement of the upper block in that direction. As such, the movement after initial pull off may thus be limited to movement in the axial direction 90. The spring 120 may function to pull the two blocks 116, 118 back together. All of the movable components 24 of the adjustable form 10 may have the disclosed feature for handling the sticking, frictional forces during movement, and it is to be understood that the example shown for movable component 94 is exemplary and that it may be employed for the other movable components 24 and a repeat of this information is not necessary.

[0054] Although described as being adjustable to form a first form surface 28 and a second form surface 48, the adjustable form 10 can be configured to form any number of form

surfaces in accordance with different exemplary embodiments. The form surfaces may be at different diameters so that different circumferences 20 are employed. In other arrangements, some of the form surfaces may share the same diameter and circumferential lengths, but have their gapless areas at different locations in the axial direction 90. The upper surfaces of the fixed length form elements 12 and the adjustable length form elements 18 may be parts made from 3D printing. There may be 12 fixed length form elements 12 and 12 adjustable length form elements 18 so that 24 form elements 12, 18 and present in which each have 15 degrees of involved angle comprising the adjustable form 10.

[0055] In operation, the adjustable form 10 can be first moved into the first form surface 28 orientation, and then the first tire 66 can be built thereon. After the first tire 66 is constructed, the movable components 18 are all moved in the outboard direction in the axial direction 90 and thus away from the axial midpoint 112. The movable components 18 may be moved to their extreme outboard positions and thus as far away from the axial midpoint 112 as possible. This movement may leave 5 or 6 millimeter gaps between the movable components 18 and the fixed length form elements 12. Next, the adjustable form 10 can be collapsed to reduce it to a smaller diameter, and this collapse may place it back into the aforementioned and described tire removal orientation. This reduction in the size of the circumference 20 and placement into a smaller diameter will allow the constructed first tire 66 to be removed from the adjustable form 10.

[0056] The adjustable form 10 can then be reenergized so that it assumes the second form surface 48 orientation that is at a diameter 110 greater than the diameter 108. The movable components 18 are retracted back so that they define with the fixed length form elements 12 the fourth and fifth build regions 50, 54 that are gapless. The second tire 76 may then be built upon the second form surface 48, and once completed, the movable components 12 can be moved outboard in the axial direction 90 to their outermost positions to leave 5-6 millimeter gaps between the movable components 12 and their adjacent fixed length form elements 12. This outward positioning of the movable components 12 makes the adjustable form 10 collapsible. The diameter of the adjustable form 10 can then be reduced to return it to the tire removal orientation, and the second tire 76 may be removed. The adjustable form 10 may then be moved back into the first or second form surface 28, 48 orientation for subsequent tire building, or may be moved to additional form surface orientations if so desired for the building of tires of different diameters and/or widths.

[0057] While the present invention has been described in connection with certain preferred embodiments, it is to be understood that the subject matter encompassed by way of the present invention is not to be limited to those specific embodiments. On the contrary, it is intended for the subject matter of the invention to include all alternatives, modifications and equivalents as can be included within the spirit and scope of the following claims.

CLAIMS

What is claimed is:

1. An adjustable form, comprising:

a plurality of fixed length form elements that are disposed around a form axis, wherein the fixed length form elements move in a radial direction to move closer to and farther from the form axis, wherein an axial length of the fixed length form elements is non-adjustable;

a plurality of adjustable length form elements that are disposed around the form axis, wherein the adjustable length form elements move in the radial direction to move closer to and farther from the form axis, wherein the fixed length form elements and the adjustable length form elements are alternatingly disposed with one another around an entire circumference of the form, wherein the adjustable length form elements have movable components that move in the axial direction to render the axial length of the adjustable length form elements adjustable, wherein the adjustable length form elements have a center component that do not move in the axial direction;

wherein the fixed length form elements and the adjustable length form elements are movable to a first radius to form a first form surface, wherein the movable components and the fixed length form elements form a first build region along a first axial length of the first form surface, wherein the movable components and the fixed length form elements form a second build region along a second axial length of the first form surface, wherein the center components and the fixed length form elements form a third build region located between the first build region and the second build region in the axial direction along a third axial length of the first form surface;

wherein gaps in the third build region defined by the center components and the fixed length form elements are larger than any gaps in the first and second build regions defined by the movable components and the fixed length form elements;

wherein the fixed length form elements and the adjustable length form elements are movable to a second radius to form a second form surface, wherein the movable components and the fixed length form elements form a fourth build region along a fourth axial length of the second form surface, wherein the movable components and the fixed length form elements form a fifth build region along a fifth axial length of the second form surface, wherein the center components and the fixed length form elements form a sixth build region located between the fifth build region and the sixth build region in the axial direction along a sixth axial length of the second form surface;

wherein gaps in the sixth build region defined by the center components and the fixed length form elements are larger than any gaps in the fourth and fifth build regions defined by the movable components and the fixed length form elements.

2. The adjustable form as set forth in claim 1, wherein gaps are defined in the first and second build regions by the movable components and the fixed length form elements on the first form surface and are less than 0.1 millimeters in width;

wherein gaps are defined in the fourth and fifth build regions by the movable components and the fixed length form elements on the second form surface and are less than 0.1 millimeters in width.

3. The adjustable form as set forth in claim 1, wherein no gaps are defined in the first and second build regions by the movable components and the fixed length form elements on the first form surface;

wherein no gaps are defined in the fourth and fifth build regions by the movable components and the fixed length form elements on the second form surface.

4. The adjustable form as set forth in any one of claims 1-3, further comprising:

a first non-pneumatic tire built upon the first form surface, wherein sidewalls of a shear band of the first non-pneumatic tire are built on the first build region and the second build region; and

a second non-pneumatic tire built upon the second form surface, wherein sidewalls of a shear band of the second non-pneumatic tire are built on the fourth build region and the fifth build region, wherein a diameter of the first non-pneumatic tire is less than a diameter of the second non-pneumatic tire.

5. The adjustable form as set forth in claim 4, wherein belt tissue of the shear band of the first non-pneumatic tire engages the fixed length form elements and the center components of the first form surface of the third build region; and

and wherein belt tissue of the shear band of the second non-pneumatic tire engages the fixed length form elements and the center components of the second form surface of the sixth build region.

6. The adjustable form as set forth in any one of claims 1-5, wherein the first axial length is 15 millimeters;

wherein the second axial length is 15 millimeters;

wherein the fourth axial length is 15 millimeters; and

wherein the fifth axial length is 15 millimeters.

7. The adjustable form as set forth in any one of claims 1-6, further comprising a plurality of air cylinders that actuate to move the movable components in the axial direction.

8. The adjustable form as set forth in claim 7, wherein each one of the adjustable length form elements has two of the movable components, wherein each one of the air cylinders is associated with each one of the movable components, wherein actuation of each one of the air cylinders causes the associated movable component to move in the axial direction relative to the center component of the adjustable length form element.

9. The adjustable form as set forth in any one of claims 1-8, wherein the fixed length form elements have an upper surface that is tapered in shape at the first, second, fourth and fifth build regions, and wherein the movable components have an upper surface that is tapered in shape at the first, second, fourth and fifth build regions.

10. The adjustable form as set forth in claim 9, wherein the tapered upper surfaces of the fixed length form elements at the first build regions are disposed in an opposite axial direction to the tapered upper surfaces of the movable components at the first build regions;

wherein the tapered upper surfaces of the fixed length form elements at the second build regions are disposed in an opposite axial direction to the tapered upper surfaces of the movable components at the second build regions;

wherein the tapered upper surfaces of the fixed length form elements at the fourth build regions are disposed in an opposite axial direction to the tapered upper surfaces of the movable components at the fourth build regions; and

wherein the tapered upper surfaces of the fixed length form elements at the fifth build regions are disposed in an opposite axial direction to the tapered upper surfaces of the movable components at the fifth build regions.

11. The adjustable form as set forth in any one of claims 1-10, wherein the first form surface has a diameter that is less than a diameter of the second form surface, wherein the third

build region has a longer length in the axial direction than the length of the sixth build region in the axial direction.

12. The adjustable form as set forth in any one of claims 1-11, wherein the movable components are all moved outwardly in the axial direction relative to an axial midpoint of the first form surface after a first non-pneumatic tire is built upon the first form surface, wherein the axially outward movement of the movable components creates gaps between the movable components and the fixed length form elements after moving from the first form surface;

wherein the movable components are all moved outwardly in the axial direction relative to an axial midpoint of the second form surface after a second non-pneumatic tire is built upon the second form surface, wherein the axially outward movement of the movable components creates gaps between the movable components and the fixed length form elements after moving from the second form surface.

13. The adjustable form as set forth in any one of claims 1-12, wherein the movable components having an upper block and a lower block, wherein the upper blocks form the first build region, the second build region, the fourth build region and the fifth build region, wherein the upper blocks and lower blocks are linked such that movement of the lower blocks causes the upper blocks to move both in the radial direction and in the axial direction.

14. The adjustable form as set forth in claim 13, wherein the upper blocks and lower blocks are linked through a spring connection, wherein the upper blocks and the lower blocks have sloped surfaces that face one another, wherein air cylinders engage the lower blocks and cause the lower blocks to move in the axial direction.

1/9

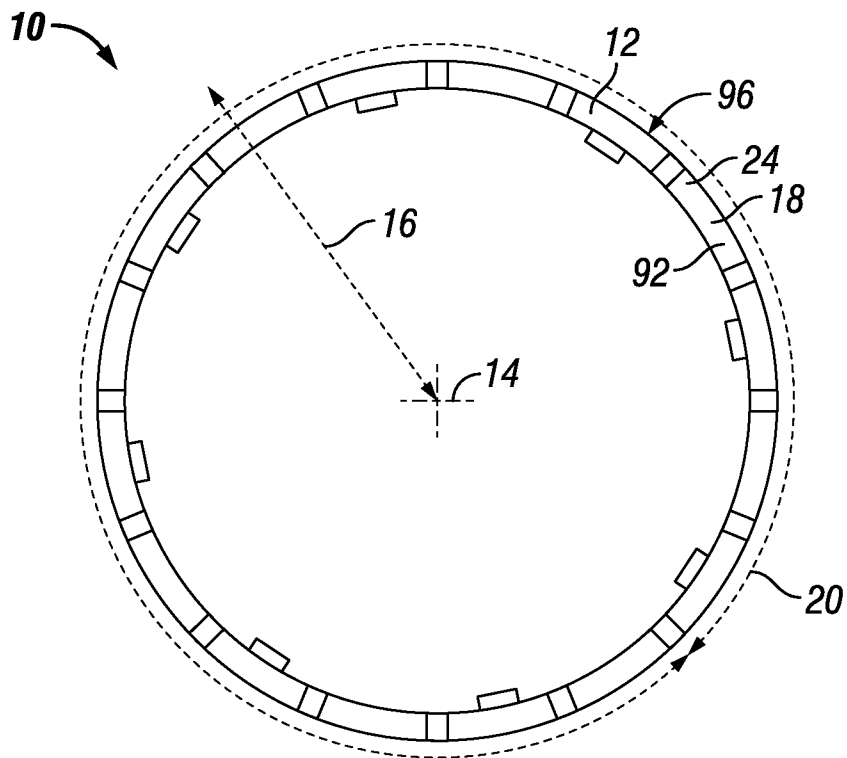


FIG. 1

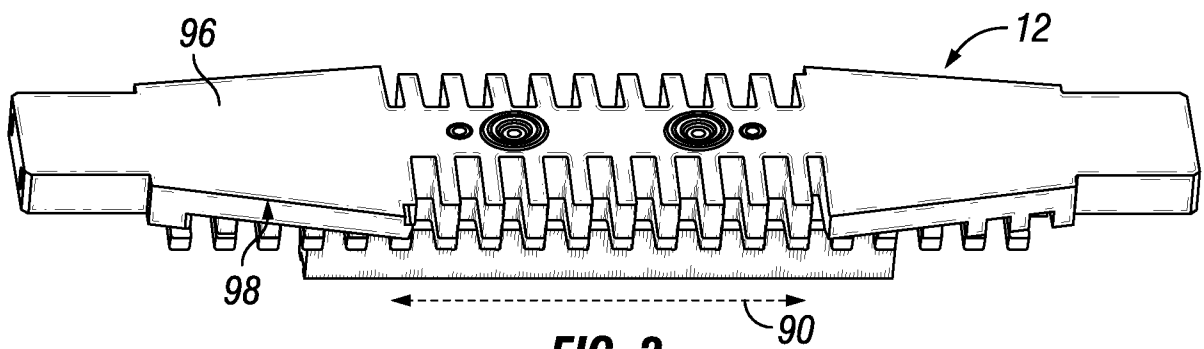


FIG. 2

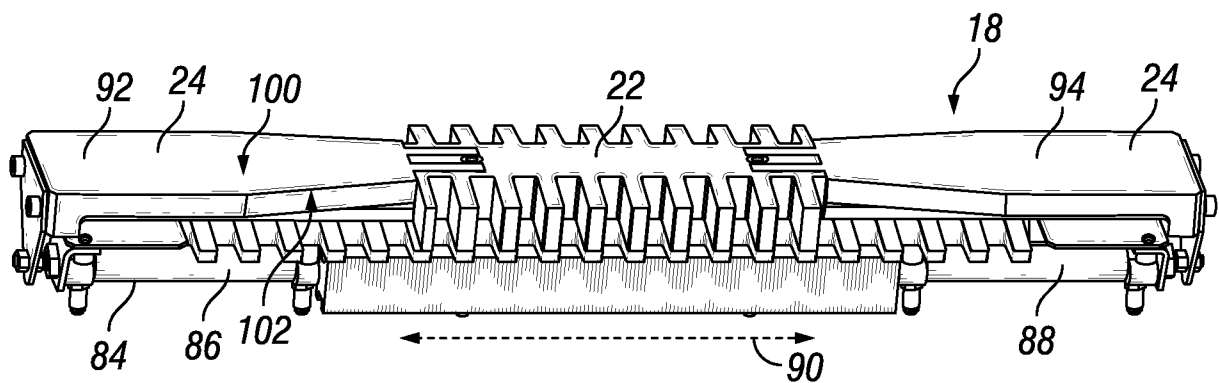


FIG. 3

2/9

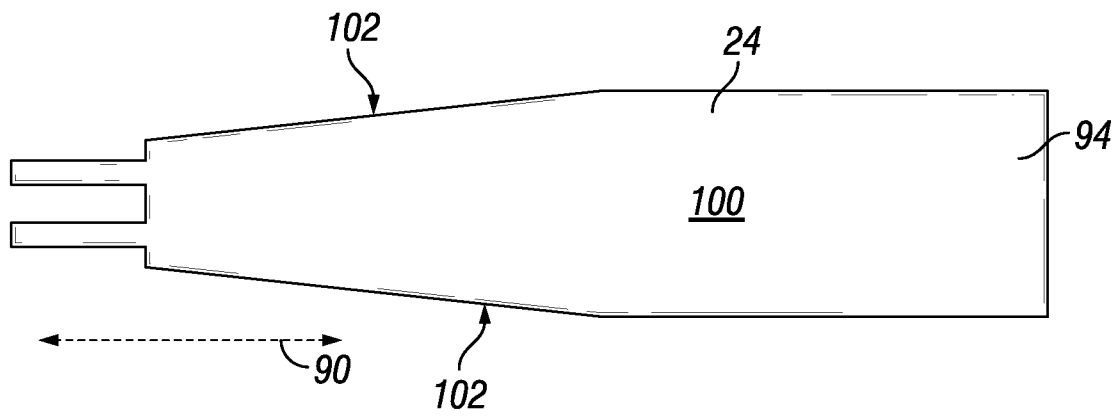


FIG. 4

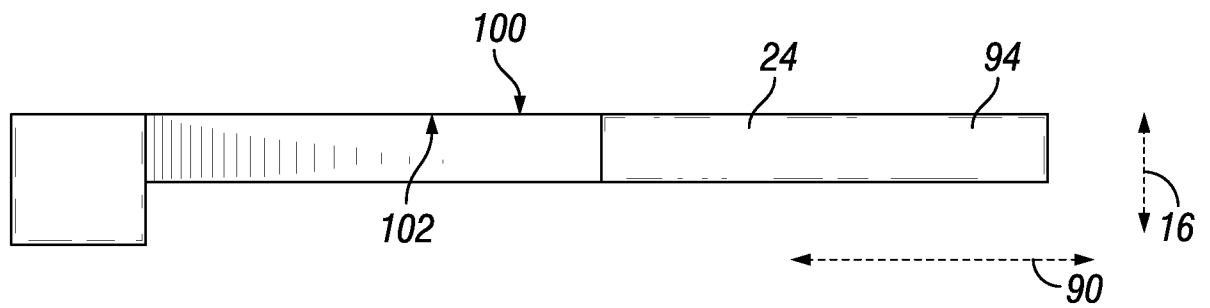


FIG. 5

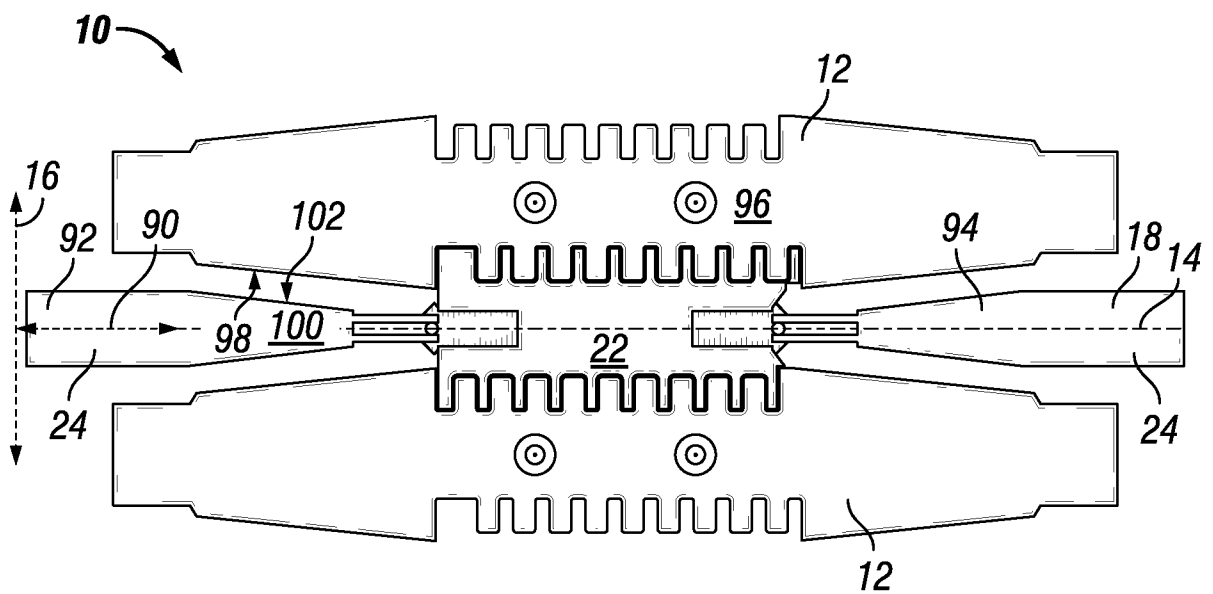


FIG. 6

3/9

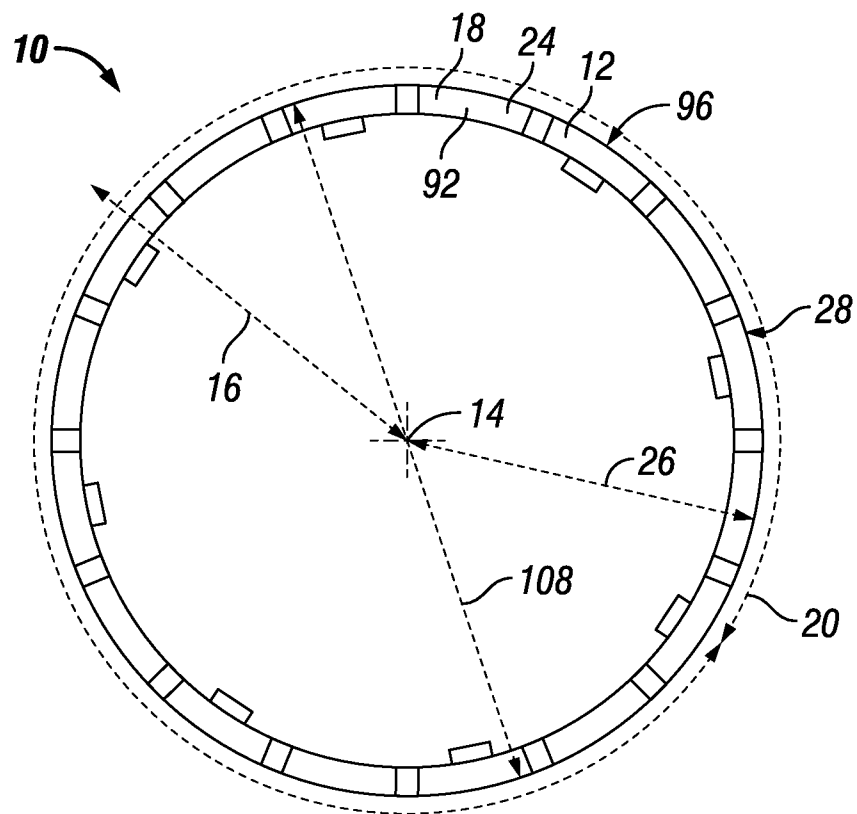


FIG. 7

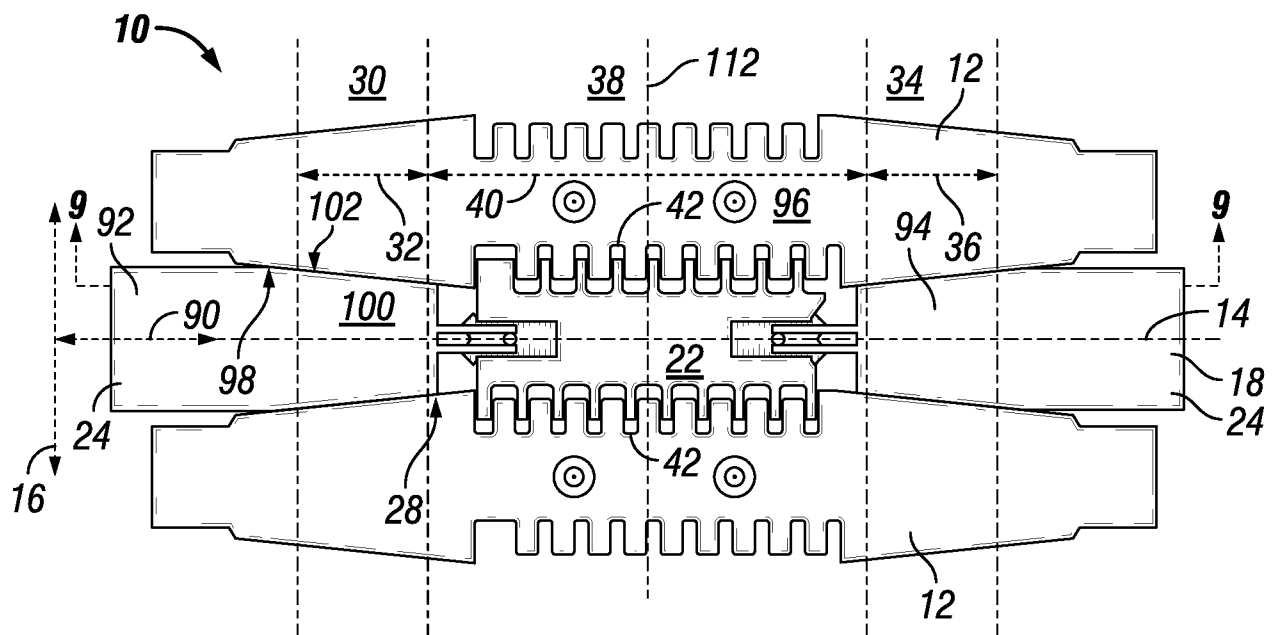


FIG. 8

4/9

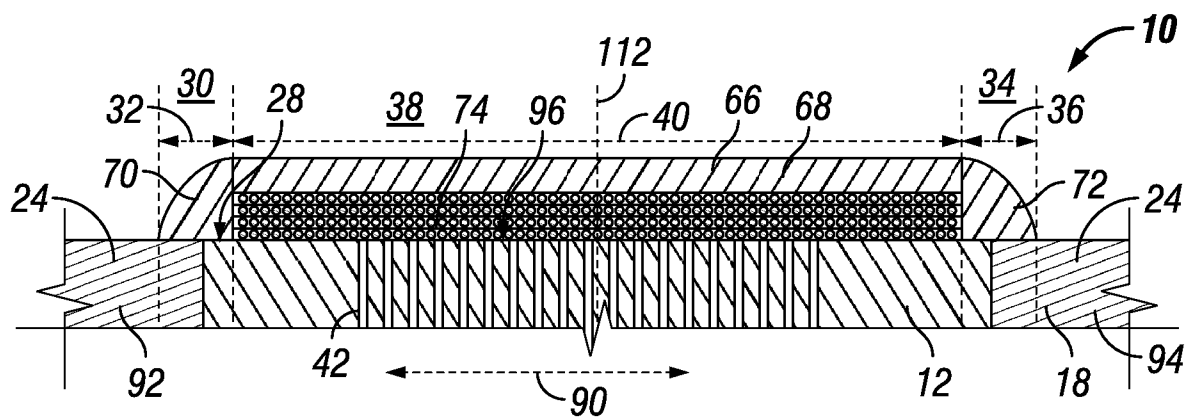


FIG. 9

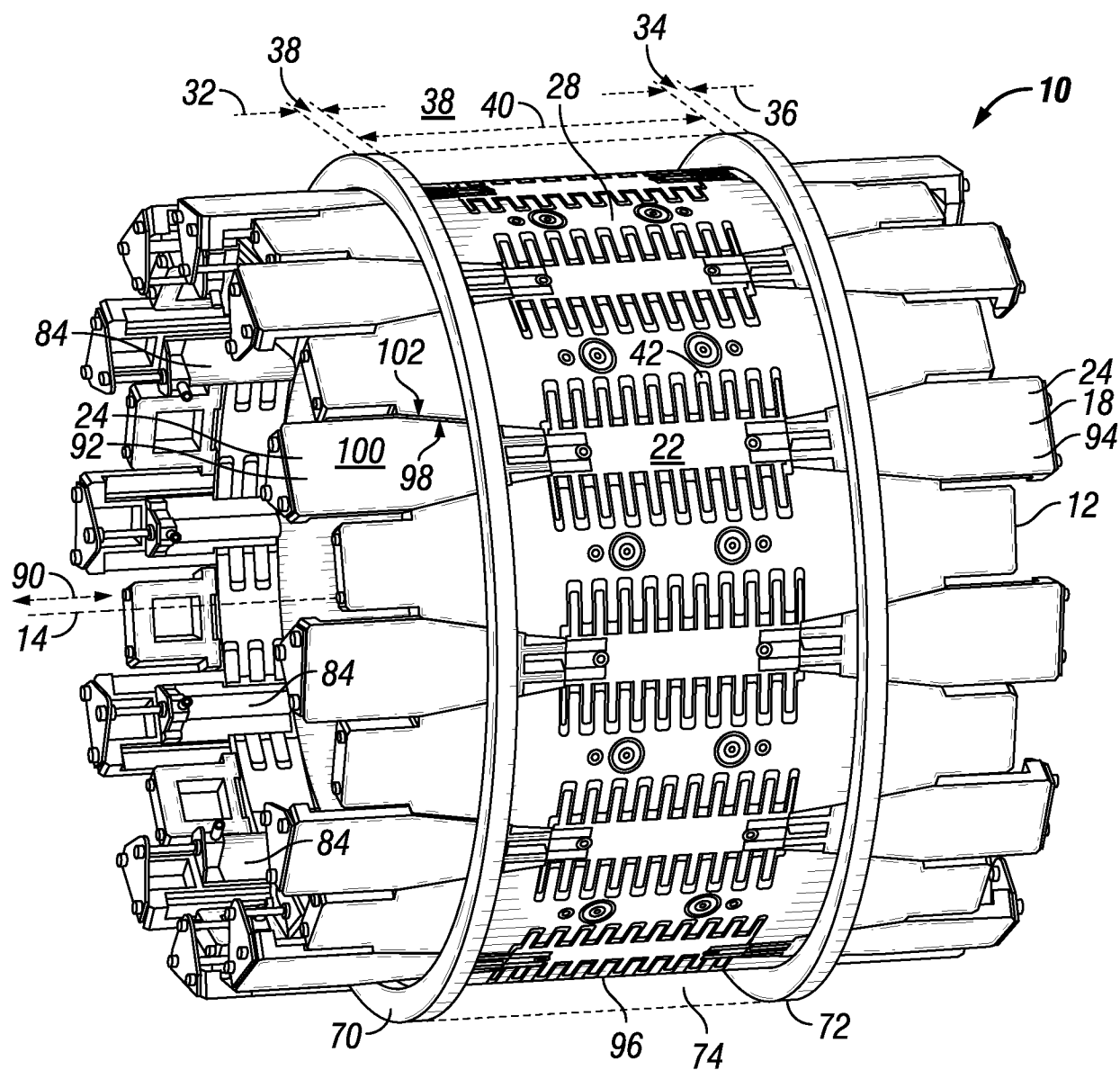


FIG. 10

5/9

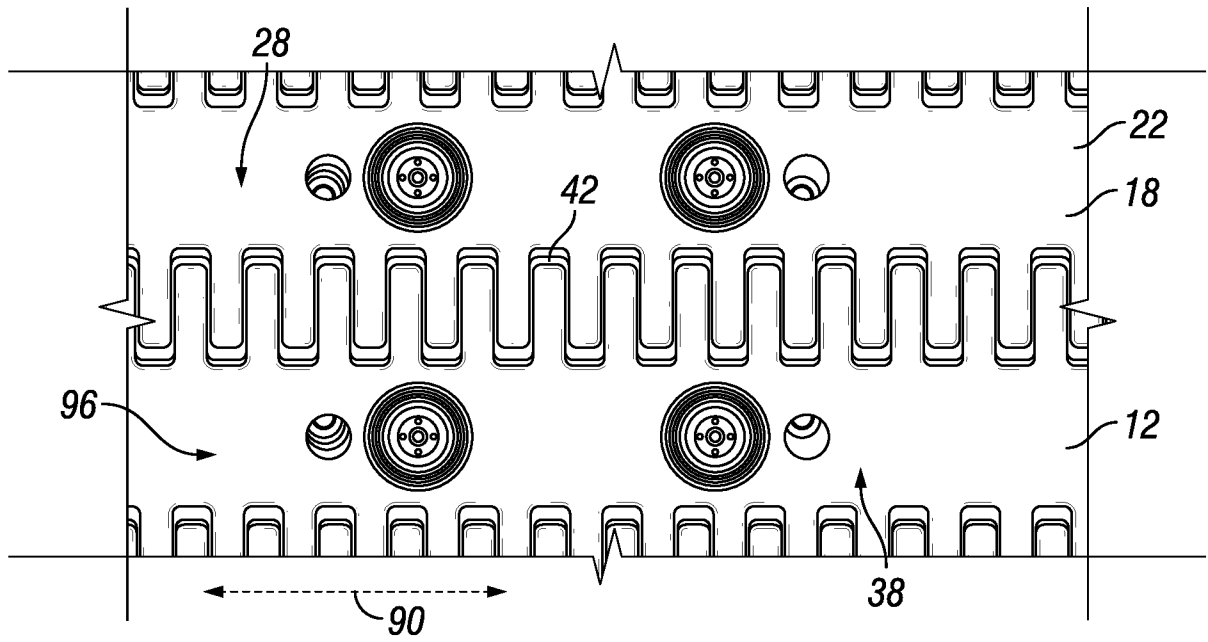


FIG. 11

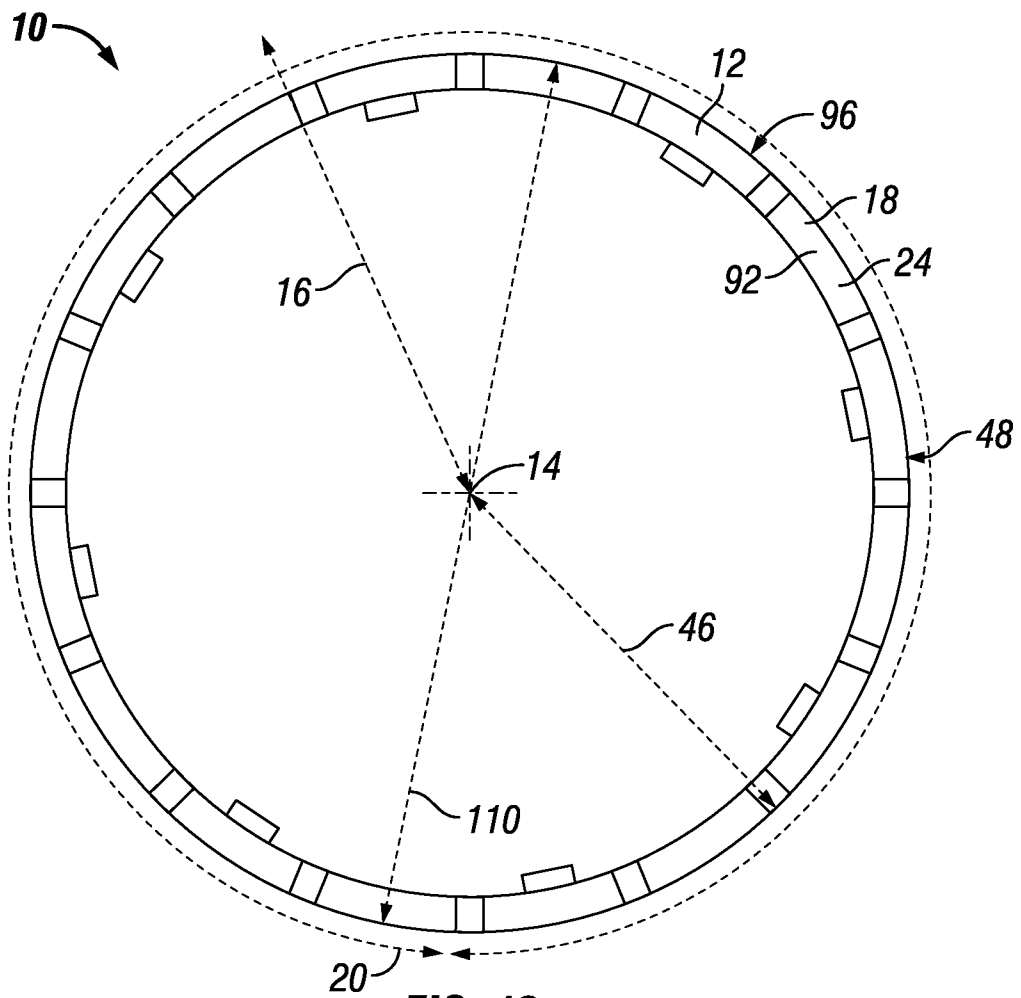


FIG. 12

6/9

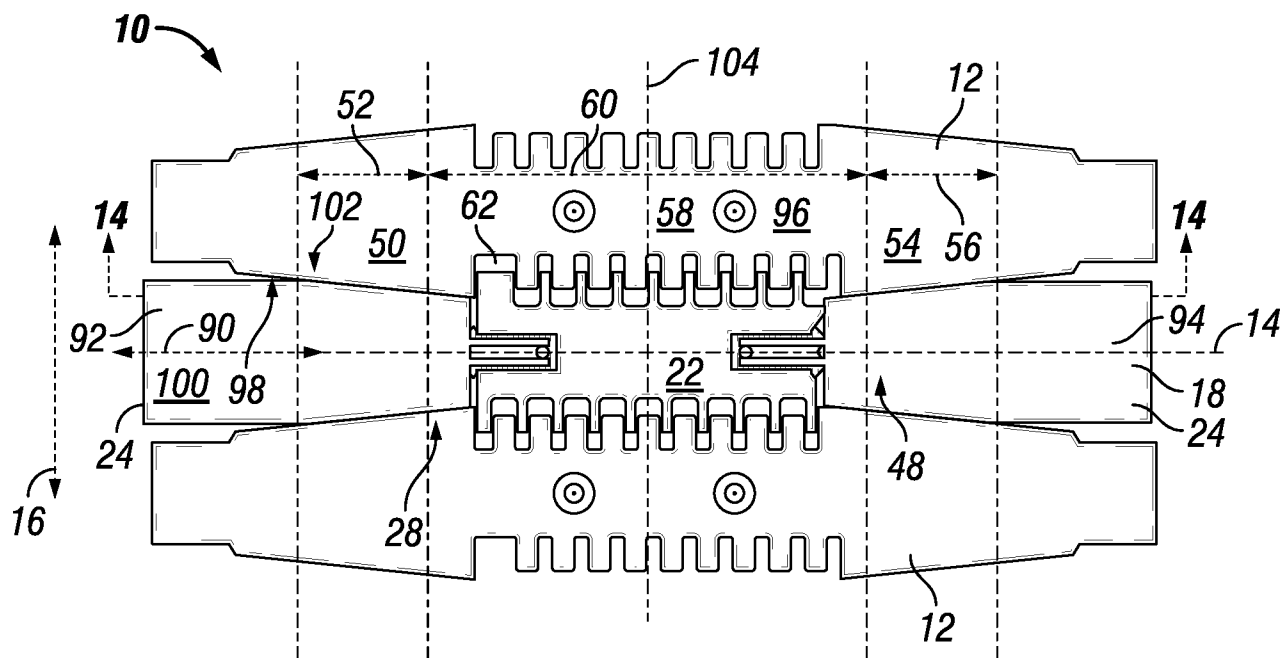


FIG. 13

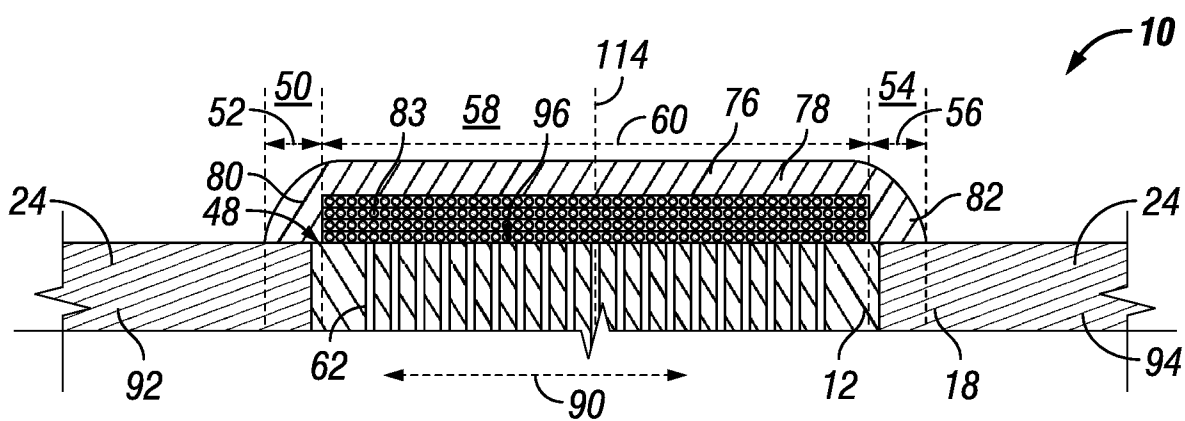


FIG. 14

7/9

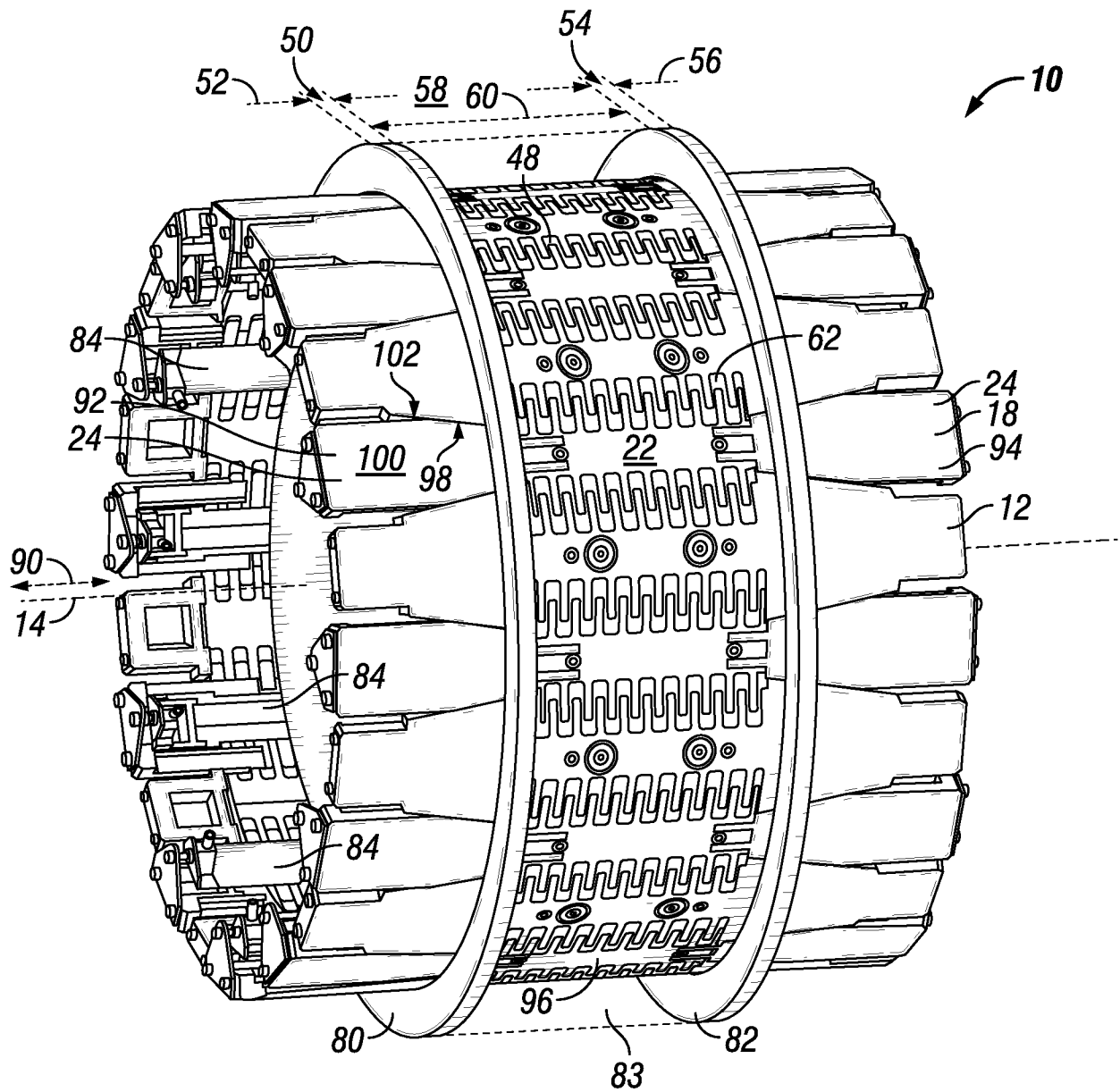


FIG. 15

8/9

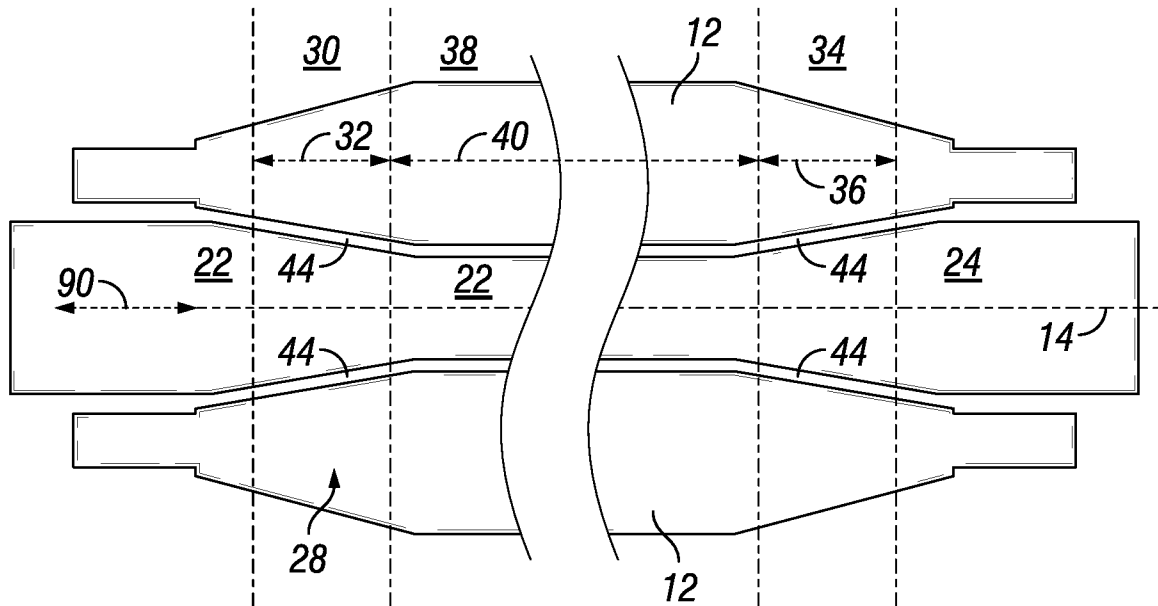


FIG. 16

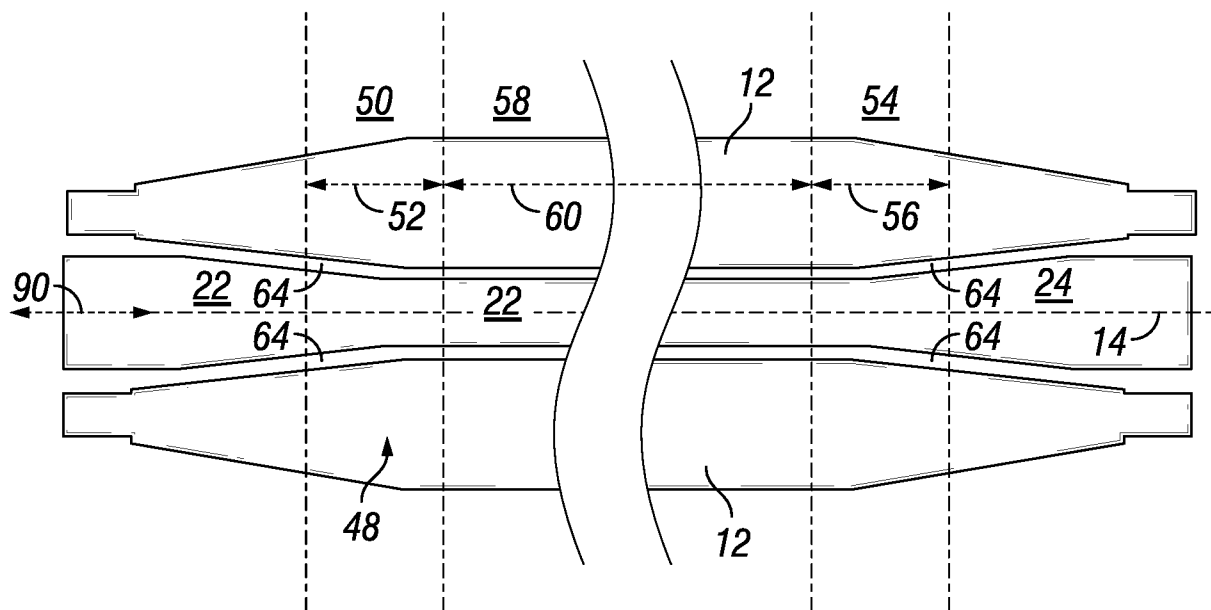


FIG. 17

9/9

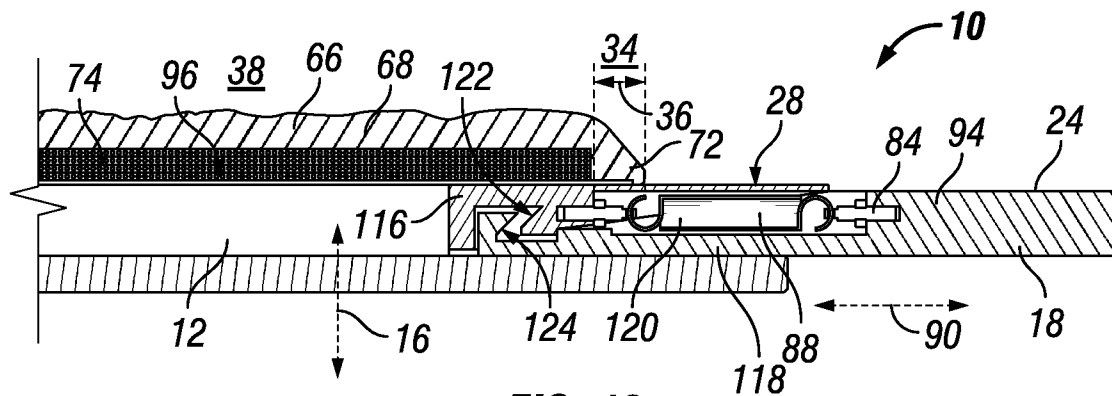


FIG. 18

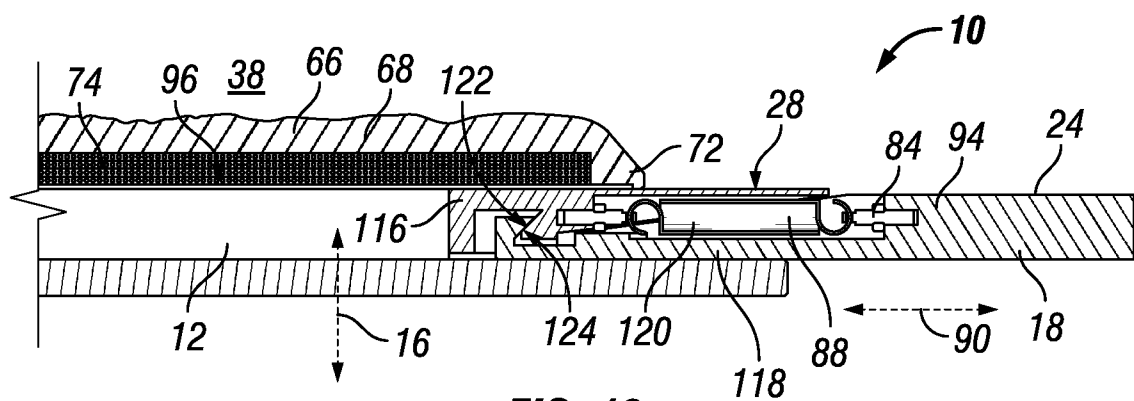


FIG. 19

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/060594

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29D30/24
ADD.

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)
B29D

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)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2013/054051 A1 (MICHELIN & CIE [FR]; MICHELIN RECH TECH [CH]; LEBLANC DOMINIQUE [FR]) 18 April 2013 (2013-04-18) page 2, line 22 - page 3, line 12 page 4, line 19 - line 21 page 6, line 34 - page 16, line 21; figures 1, 2, 26, 27, 28 -----	1-14
A	US 2016/167327 A1 (DELORME JEAN-CLAUDE [FR] ET AL) 16 June 2016 (2016-06-16) abstract; figures 1-3 -----	1-14
A	CN 2 521 029 Y (SAIXIANG SCIENCE & TECHNOLOGY [CN]) 20 November 2002 (2002-11-20) abstract; figures 1-6 -----	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

21 December 2017

Date of mailing of the international search report

12/01/2018

Name and mailing address of the ISA/

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Authorized officer

Vetter, Christoph

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2017/060594

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