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(54) Title: DEVICE FOR COMMINUATION OF MATERIAL

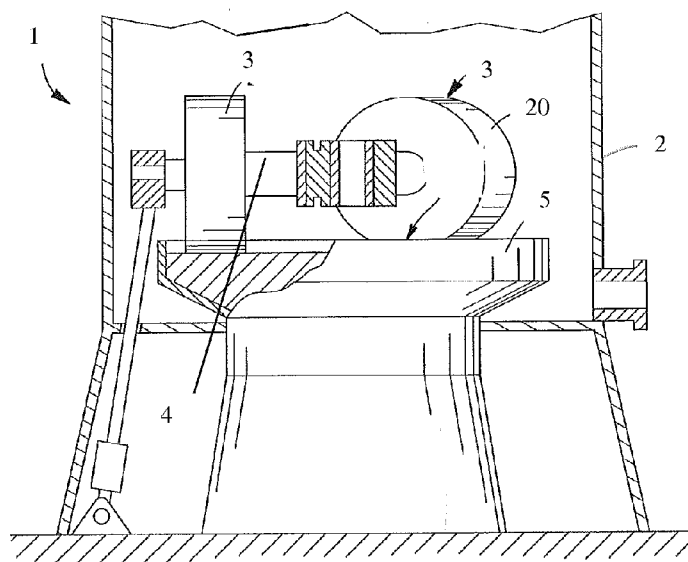


FIGURE 1

(57) Abstract: A crushing device includes at least one movable crushing body that is moved to comminute material. The crushing body may include a plurality of wearable bodies that are attachable to a roller body or first body. The wearable bodies may alternatively be attached to a sleeve segment, sleeve, or intermediate body that is attachable to the first body or the roller body. At least one fastener may extend from a respective one of the wearable bodies to the sleeve, sleeve segment, roller body, first body, or intermediate body to attach the wearable bodies to that other structure. At least one plug may be positioned in each of the wearable bodies to cover an end of the at least one fastener. Each plug may be within a channel formed in the wearable body in which it is positioned.



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DEVICE FOR COMMINUATION OF MATERIAL

CROSS REFERENCES TO RELATED APPLICATIONS

This is an international (PCT) application of Danish Priority Patent Application
5 No. PA-2012-70781 filed on 12 December 2012 which also relates to
PCT/US2012/070249 filed on December 18 2012 that claims the benefit of US
Provisional Patent Application No. 61/578,275 filed on December 21, 2011.

FIELD OF THE INVENTION

10 The present invention relates to rollers for devices configured to comminute
material such as ore, rock, minerals, stone, agglomerated material, cement
clinker, or other material. Examples of such devices are roller mills, roller
presses, vertical mills, vertical roller mills and other types of crushing devices.

15 BACKGROUND OF THE INVENTION

Some types of mills and other crushing devices often include one or more rollers
that roll to crush material against a grinding surface. The grinding surface may be
an anvil, a table or a rotatable table below the rotating rollers. Other types of
crushing devices, such as roller presses, may have rollers that are spaced apart
20 from each other to define a nip. Material may be crushed or otherwise
comminuted in the nip by the rotation of the rollers. Examples of crushing
devices or crushing bodies used in such devices may be appreciated from U.S.
Patent Nos. 252,755, 278,272, 412,558, 1,225,061, 1,589,302, 3,760,477,
3,955,766, 3,964,717, 4,034,461, 4,369,926, 4,382,561, 4,485,974, 4,582,260,
25 4,848,683, 5,203,513, 5,542,618, 5,704,561, 5,823,450, 6,523,767, 7,510,135,
7,523,794, 7,637,446, 7,946,518, 7,954,743, and U.S. Patent Application
Publication No. 2009/0218429. German Patent Nos. 4400797 and 2643307 and
International Publication No. WO 2008/132137 also disclose examples of
crushing bodies used in crushing devices.

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Crushing bodies used in crushing devices often include a wearable surface. The
wearable surface often experiences wear as material is crushed by the crushing
body. As the crushing body experiences wear, portions of the wearable surface

may erode or become broken during use and subsequently requires replacement or repair.

Rollers of crushing devices may have an outer surface used to compact and comminute material. Rollers may include a liner that defines the outer surface of the roller. The outer surface is typically formed of metal and experiences wear during operation of the roller. Inserts may be positioned in the wear surface of the roller. The inserts may be composed of a material that is harder than other portions of the surface such as the liner of the roller or the outer surface of the roller. For instance, the inserts may be composed of carbide or tungsten carbide. U.S. Patent Nos. 5,269,477, 5,203,513, and 412,558 disclose examples of the use of inserts in wear surfaces of a roller used for comminuting material.

An insert may be attached to a roll body by glue or an adhesive or other means. Rollers with such a wear surface often experience insert cracking, breaking or fall out because the glue or adhesive fails to provide a sufficient bond with a roll body to withstand the extreme pressures associated with grinding and crushing material.

Some wearable surfaces used in crushing devices include hexagonal tiles, such as the tiles disclosed in U.S. Patent No. 5,755,033. A tiled surface is adhered directly to a roll surface base material and can be arranged with or without gaps between the tiles. The tiles are usually relatively thin and made of materials harder than the base material. During use, the tiles can break free from the base material when crushing material, which may expose the base material to the grinding process and thereby damage the base material. The tiles must be reattached or replaced to repair the roll surface and prevent damage to the base material. The reattachment or replacement of any missing tile may result in a less secure attachment than what was initially provided, however, which may make the tile more likely to again break free during use.

Rollers and other crushing bodies of crushing devices often experience uneven and relatively high rates of wear and, as a result, often have the wear surfaces of

such rollers replaced or repaired. When such replacement or repairing is needed, substantial costs in terms of lost operational capacity as well as the costs associated with the repair or replacement of the crushing body or crushing device can be experienced by an operator of a crushing device.

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We have determined that a new crushing body is needed that may increase the life of crushing bodies or facilitate improved maintenance for repairing crushing bodies or maintaining the crushing bodies. It should be understood that embodiments of our crushing body may be included in crushing devices used to comminute material.

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SUMMARY OF THE INVENTION

A crushing device having at least one crushing body is provided. Additionally a crushing body is provided. Embodiments of a crushing body may include a crushing surface that is sized and shaped to facilitate comminution of material when the crushing body is moved (e.g. rotated, vertically moved, or otherwise moved). The crushing body may include at least one first member, a plurality of wearable bodies attached to the at least one first member to define the crushing surface, and a plurality of fasteners. Each of the wearable bodies having a channel formed therein and each of the fasteners may be partially positioned within the channel of a respective one of the wearable bodies and extend through that wearable body to attach that wearable body to the at least one first member.

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The crushing body may be any of a number of possible structures used to impact or engage material to comminute or otherwise crush material such as ore, rock, minerals, agglomerated material, stone, rock, cement clinker, or other material. For instance, the crushing body may be a roller, a wear surface for a table or a wear surface for an anvil. It should be appreciated that the crushing device for that particular crushing body may be a mill, roller mill, roller press, vertical roller mill, vertical mill, or other type of comminution device.

The wearable bodies may be configured to cover an entirety of an outer surface

of the at least one first member to which those wearable bodies are attached for defining the crushing surface of the crushing body. For instance, the at least one first member may be a plurality of first members that are each connected together to form a sleeve that is sized for attachment to a roller body and the
5 wearable bodies may be attached to an outer surface of the first members to define the crushing surface of the sleeve. In other embodiments, the first member may be a roller body and the wearable bodies may define the crushing surface of the roller body. Edge protection elements may be attached adjacent opposite ends of the roller body as well. For example, there may be a first set of
10 edge protection elements and a second set of edge protection elements. The first set of edge protection elements may be positioned adjacent a first end of the crushing body and the second set of edge protection elements may be positioned adjacent a second end of the crushing body that is opposite the first end of the crushing body.

15 In some embodiments of the crushing body, each of the fasteners may be partially positioned within the channel of a respective one of the wearable bodies such that a head end of each fastener is positioned below an outer surface of the wearable body to which that fastener is attached. A plurality of plug may also be
20 included in the crushing body. Each of the plugs can be attached to a respective one of the wearable bodies within the channel of that wearable body such that the plug covers the fastener within that channel. A plug may include one or more inserts such as carbide insert for example. An adhesive or filler material may also be positioned with the channel of each of the wearable bodies such that the
25 adhesive or the filler material covers the head end of the fastener within the channel and engages the plug within that channel.

It should be appreciated that the each of the at least one first member may have a plurality of apertures defined therein. Each of the apertures may be shaped to
30 receive a respective one of the wearable bodies. The at least one first member may also have at least one opening in communication with each of the at least one aperture. Each of the at least one openings is sized to receive a portion of a respective one of the fasteners.

In some embodiments of the crushing body, the crushing body may include a roller body and the at least one first member may be comprised of a plurality of intermediate members. Each of the intermediate members has a first side that
5 engages the roller body and a second side that engages a respective one or more of the wearable bodies.

The fasteners of the crushing body may be any of a number of different types of suitable fastener elements. For instance, the fasteners may be bolts, screws, or other types of fastener elements.

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In some embodiments of the crushing body, the wearable bodies may be considered first wearable bodies and the crushing body may also be comprised of second wearable bodies that do not have any fasteners positioned therein. The crushing body may be comprised of a first column of wearable bodies that
15 extend circumferentially along a curved surface area of the at least one first member. The wearable bodies of the first column of wearable bodies may comprise the first wearable bodies and the second wearable bodies. The first column of wearable bodies extends so that the wearable bodies extend circumferentially in series and the first wearable bodies and second wearable
20 bodies alternate one after the other along the first column such that each of the first wearable bodies is immediately adjacent on opposite sides with second wearable bodies. Each of the first wearable bodies may be positioned in a respective first recess within the at least one first member and each of the second wearable bodies may be positioned in a respective second recess within
25 the at least one first member. A depth of the first recess is deeper or shallower than a depth of the second recess.

In some embodiments, the at least one first member has a profile on an outer surface to facilitate attachment to the wearable bodies. For example, the at least
30 one first member may have a plurality of rails defined thereon and a plurality of holes formed in the rails and each of the wearable bodies may have a first side that has a groove sized to receive a portion of a respective one of the rails and a projection sized to be received within a respective one of the holes. As another

example, the at least one first member have a profile defined by a plurality of apertures. Each of the apertures may include a first recess and a second recess having a lesser depth within the first member than the first recess. A respective wearable body may be positionable in the first and second recesses of a
5 respective one of the apertures for being attached to the first member.

The wearable bodies of the crushing body may be configured to include multiple channels. For example, the channel of the wearable body may be considered a first channel and there may be one or more second channels formed within that wearable body as well. In addition to the fastener partially within the first channel,
10 there may also be one or more second fasteners for being partially positioned within the at least one second channel so that the at least one second fastener extends from that second channel of the wearable body to the at least one first member to attach that wearable member to the first member.

15 In some embodiments, the wearable members may be arranged along a curved surface area of the crushing body in a plurality of columns. Each of the columns may extend circumferentially along the curved surface area of the crushing body. The columns may comprise a first column of the wearable bodies, a second column of the wearable bodies and a third column of the wearable bodies. The
20 first column of wearable bodies may be adjacent a first end of the crushing body. The second column of wearable bodies may be adjacent a second end of the crushing body that is opposite the first end. The third column of wearable bodies may be between the first and second columns of wearable bodies. The wearable bodies of the third column of wearable bodies may have a lower or higher
25 hardness, strength or toughness than the wearable bodies of the first and second columns of wearable bodies. The columns of wearable bodies can also be comprised of a fourth column of wearable bodies that is positioned between the first and third columns of wearable bodies and a fifth column of wearable bodies that is positioned between the second and third column of wearable
30 bodies. The wearable bodies of the third column of wearable bodies may have a lower or higher hardness, strength or toughness than the wearable bodies of the fourth and fifth columns of wearable bodies. The wearable bodies of the fourth column of wearable bodies may have a lower or higher hardness, strength or

toughness than the wearable bodies of the first column of wearable bodies. The wearable bodies of the fifth column of wearable bodies may have a lower or higher hardness, strength or toughness than the wearable bodies of the second column of wearable bodies. The wearable bodies of the first, second, third, fourth, and fifth columns of wearable bodies may each have at least one plug element positioned therein.

Other details, objects, and advantages of the invention will become apparent as the following description of certain present preferred embodiments thereof and certain present preferred methods of practicing the same proceeds.

Brief Description of the Drawings

Present preferred embodiments of crushing devices and rollers having wear surfaces that may be used in such devices are shown in the accompanying drawings and certain present preferred methods of practicing the same are also illustrated therein. It should be appreciated that like reference numbers used in the drawings may identify like components.

Figure 1 is a three dimensional image of a first embodiment of a crushing device.

Figure 2 is a cross sectional view of a second embodiment of a crushing device.

Figure 3 is a perspective view of a first exemplary embodiment of a roller that may be used in embodiments of the crushing device.

Figure 4 is a cross sectional view of the first exemplary embodiment of the roller.

Figure 5 is an enlarged fragmentary view of the first exemplary embodiment of the roller shown in Figure 4.

Figure 6 is a perspective view of the first exemplary embodiment of the roller with a segment of the crushing body cut away from the roller.

Figure 7 is a perspective view of an exemplary embodiment of a segment of the crushing body of the first exemplary embodiment of the roller.

- 5 Figure 8 is a perspective view of an exemplary embodiment of a wearable body of the first exemplary embodiment of the roller.

Figure 9 is a cross sectional view of the exemplary embodiment of the wearable body of the first exemplary embodiment of the roller.

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Figure 10 is a perspective view of the segment of the crushing body of the first exemplary embodiment of the roller with a plurality of the wearable bodies removed.

- 15 Figure 11 is a fragmentary front view of a second exemplary embodiment of a roller for a crushing device.

- 20 Figures 12A-12C are a perspective views of exemplary embodiments of a wearable bodies that are attachable to a member such as a sleeve, sleeve segment, or roller body of a crushing body or an intermediate body of different embodiments of the crushing body that is includable in an embodiment of the crushing device.

- 25 Figure 12D is a perspective view of an exemplary embodiment of a crushing body employing a particular combination of the wearable bodies shown in Figures 12A-12C.

- 30 Figure 13 is a perspective view of a first exemplary embodiment of a crushing body that may be utilized in embodiments of a crushing device. Some wearable bodies and edge protection elements are cut away from the member, which may be for example a sleeve that is formed as a unitary body or formed of multiple segments that are connected to each other. This embodiment of the crushing body may be configured to be a member that is formed and subsequently

attached to or otherwise installed on a roller body or roller shaft. After the member is attached to the roller body or shaft, wearable bodies may be attached to the member.

- 5 Figure 14 is a front fragmentary view of a second exemplary embodiment of the crushing body that maybe utilized in embodiments of a crushing device. The view of Figure 14 is applicable to the first, second, third or fourth exemplary embodiments of the crushing body and the first and second embodiments of the roller.

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Figure 15 is a perspective view of a third exemplary embodiment of a crushing body that may be used in embodiments of the crushing device.

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Figure 16 is a fragmentary top perspective view of the third exemplary embodiment of a crushing body that may be used in embodiments of the crushing device with a number of wearable bodies and edge protection elements being cut away to illustrate a configuration of the body of the crushing body that is shaped to facilitate attachment of the wearable bodies..

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Figure 17 is a cross sectional view of the third exemplary embodiment of the crushing body that may be used in embodiments of the crushing device taken along line XVII-XVII in Figure 16.

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Figure 18 is a perspective view of a fourth exemplary embodiment of a crushing body that may be used in embodiments of the crushing device.

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Figure 19 is a fragmentary cross sectional view of the fourth exemplary embodiment of the crushing body that may be used in embodiments of the crushing device.

Figure 20 is a bottom perspective view of a wearable body that may be utilized in embodiment of the fourth exemplary embodiment of the crushing body.

Figure 21 is a top perspective view of the fourth exemplary embodiment of the crushing body that may be used in embodiments of the crushing device with wearable bodies and edge protection elements removed to illustrate underlying
5 structure of the crushing body.

Figure 22 is a perspective view of a fifth exemplary embodiment of the crushing body that may be used in embodiments of the crushing device.

10 Figure 23 is an enlarged fragmentary view of the fifth exemplary embodiment of the crushing body that may be used in embodiments of the crushing device with segments cut away to better illustrate attachment of one wearable body segment to a roller body or a sleeve of the crushing body.

15 Figure 24 is a perspective middle cutaway view of a sixth exemplary embodiment of the crushing body that may be used in embodiments of the crushing device.

Figure 25 is a fragmentary perspective side view of a seventh exemplary embodiment of the crushing body that may be used in embodiments of the
20 crushing device.

DETAILED DESCRIPTION OF PRESENT PREFERRED EMBODIMENTS

Referring to Figure 1, a crushing device 1 may include a housing 2 that encloses a plurality of rollers 3 that each rotate about a roller shaft to comminute material
25 such as ore, rock, mineral, stone, agglomerated material, or other material. Each roller 3 may roll about its own respective roller shaft 4 that is connected to a vertical shaft (not shown). For instance, each of the rollers 3 may have a central opening that receives its own roller shaft 4 about which the roller 3 rotates. Each roller shaft 4 may be attached to a vertical shaft. In some
30 embodiments, the vertical shaft may not rotate. In other embodiments, the vertical shaft may rotate. Additionally, the roller shafts 4 may rotate to rotate the rollers 3. Material may be fed onto a table 5 on which the material is crushed by the rotating rollers to comminute material to a desired size or range of sizes. In

some embodiments, the table 5 may rotate. In other embodiments, the table 5 may not rotate.

Referring to Figure 2, a crushing device may alternatively be configured as a roller press and include a housing that encloses and supports a plurality of spaced apart rollers 3. Two rollers 3 may be spaced apart from each other to define a nip 13. The rollers 3 rotate about a roller shaft or are otherwise connected to a drive mechanism that drives rotation of the rollers 3. Material may be fed to the crushing device 1 via a feed device 10 to feed material for being comminuted by the two rollers 3. The feed device 10 may include a feed conduit 9 that defines an opening through which material may pass into the crushing device for being fed to the rollers 3 for comminution. The feed conduit 9 may direct the material to be comminuted to the nip 13 or other location between the rollers 3 to facilitate comminution of the material fed to the crushing device.

Each of the rollers 3 may be a crushing body. The rollers may include a wear surface formed on the crushing surface of the roller. In some embodiments, the wear surface may be defined by wearable bodies directly attached to a roller body. In other embodiments, the wear surface may be defined by wearable bodies attached to an intermediate body such as a connector body that is positioned within the roller body or a sleeve that is positionable over a roller body and attachable to the roller body. As yet another example, the wear surface of the rollers 3 may be defined by wearable bodies that are attached to a segment of a sleeve. Each segment may then be connectable to other segments to form a sleeve around a roller body. Each segment may be attached to the roller to define the wear surface of the roller.

Referring to Figures 3-10, a crushing body 20 may be attached to a roller body 19 or may be a part of the roller body 19. The crushing body 20 may include a wearable surface defined by wearable bodies 21. Edge protection elements 23 may be attached to the roller body 19 adjacent wear bodies at opposite ends of the roller 3. The edge protection elements could alternatively be replaced with additional columns of wearable bodies that extend in a circumferential direction C around the crushing body (e.g. extend circumferentially) around the crushing

body 20. The opposite ends of the roller body 19 may be adjacent the mouths, or ends, of a central channel 19a that is formed in the roller body 19 and is sized to receive a roller shaft 4 that rotates to rotate the roller body 19 and any wearable surface or crushing body formed on or attached to the roller body 19. In some
5 embodiments, it is contemplated that a roller body 19 may be formed so that a roller shaft 4 may be integrally formed with or integrally attached to the roller body 19 where the central channel 19a is located.

10 The crushing body 20 may also include a member such as a sleeve that is a unitary structure or a sleeve formed by interconnected segments 27 of a sleeve. The sleeve that is formed may have an inner channel that is sized to receive a roller body 19 so that the sleeve is positionable around the roller body and attachable to the roller body 19. The sleeve may be on a surface area of the roller body that is opposite the inner surface area of the roller body that encircles
15 the central channel 19a. In alternative embodiments, the member 34 may be the roller body to which the wearable bodies are directly attached that has a central channel that receives the roller shaft and is attached thereto or is otherwise attached to the roller shaft 4.

20 The wearable bodies 21 of the crushing body 20 may each be positioned within a respective opening or recess formed in the segment 27 or an intermediate body that is attached to both the wearable bodies and the roller body for attaching the wearable bodies 21 to the roller body 19. Fasteners 28 may extend from the wearable bodies 21 to the member 34. For instance, fasteners 28 may extend
25 from the wearable bodies to a sleeve segment 27 or intermediate body to attach the wearable bodies to the segment 27.

30 Alternatively, the wearable bodies 21 may be directly attachable to the roller body 19 by being positionable on the roller body 19 or within an opening, groove, channel or other aperture in the roller body 19. For instance, fasteners 28 may extend from the wearable bodies 21 into the roller body 19 for directly attaching the wearable bodies to the roller body. The wearable bodies may also include a bottom profile for mating with a profile formed on the surface of the roller body 19

(e.g. each wearable body may have one or more projections and apertures for mating with one or more recesses defined in the roller body 19).

As may be appreciated from Figures 8-12, the wearable bodies 21 may be any of
5 a number of shapes and sizes to facilitate positioning and attachment of the
wearable bodies to the member 34 for defining a wearable surface that directly
contacts material to comminute the material when the crushing body 20 is
operated in a crushing device. For instance, the wearable body 21 may be
hexagonal in shape and include a central channel through which a fastener 28
10 extends so that a head end 28a of the fastener is adjacent the top of the
wearable body 21 and the tail end 28b of the fastener extends from the bottom of
the wearable body for insertion into a hole in the roller body 19 or a segment 27
or other intermediate body to which the wearable body 21 is attachable for being
attached to the roller body 19. The tail end 28b and intermediate portion of the
15 fastener 28 that extends below the head end 28a may be threaded for mating
with threads within a hole or other aperture 31 in the segment 27, other type of
intermediate body, or roller body 19. The threads of the tail end 28b may also
mate with threads within a central channel 57 of the wearable body.

20 The wearable bodies may be positionable adjacent to each other so that
immediately adjacent wearable bodies engage or interlock with one another and
the wearable bodies define a wear surface along the lateral surface area, or
curved surface area, of the crushing body 20. Epoxy or other adhesive may be
positioned on sidewalls of the wearable bodies to facilitate interconnections
25 between immediately adjacent wearable bodies. Each sidewall of a wearable
body may also be configured to engage sidewalls of immediately adjacent
wearable bodies to provide an interference fit with adjacent wearable bodies as
well to help ensure the wearable bodies stay positioned next to each other when
the crushing body is in use to comminute material. In some embodiments, an
30 interference fit may not exist between immediately adjacent wearable bodies due
to tolerance ranges for manufacturing purposes but such wearable bodies may
still be close to each other and an adhesive material or welding may also be

utilized to help attach the immediately adjacent wearable bodies to each other or to fill any gap or space between the immediately adjacent wearable bodies.

5 The top 26 of the wearable bodies 21 may each define a profile for receiving material that may help define a crushing characteristic or wear profile of the wearable body. For instance, the profile may include a plurality of grooves 26b, recesses or other types of apertures. Different walls, lips, protuberances or other detainment members 26b may be positioned within the apertures to help entrain material within the grooves 26b or to facilitate the crushing of material. The tops
10 of the walls 26c that define the grooves 26b may be configured to directly engage material to crush that material. The detainment members 26a may be recessed or flush with the tops of the walls 26c.

Each of the grooves 26b formed in the wearable body may extend for a
15 predetermined distance or over a predetermined area of the top of the wearable surface. For instance, the grooves may encircle an inner portion of the wearable body through which a fastener 28 is positioned. Alternatively, the grooves may extend linearly along a portion of the top of the wearable body 21. In yet another alternative, the outer surface of the wear body may be smooth or configured with
20 deep dimples or other features that may be back filled with materials that would promote the establishment of an autogenous layer during comminution operations.

As an alternative, the wearable body 21 may be polygonal shaped and include a
25 plurality of projections and grooves within sidewalls of the wearable body. For instance, the wearable body 21a has a central channel through which a fastener extends and includes a polygonal shaped body that has a plurality of grooves and protuberances as shown in Figure 11. The grooves are sized to receive other protuberances extending from other wearable bodies 21a. The grooves
30 may provide an interference fit or may be configured slightly looser due to manufacturing tolerances. Epoxy or other type of adhesive or welding may also be used to help facilitate attachment between sidewalls of immediately adjacent wearable bodies 21a.

As yet another alternative wearable bodies 21 may be generally square or rectangular in shape and include multiple grooves 21c formed in a top portion of the wearable surface to facilitate retaining comminuted material such as the
5 wearable bodies 21b shown in Figure 12A. The bottom portion 21d of the wearable bodies may include a cylindrical projection that defines a central opening or channel through which a fastener may pass. The head of the fastener may be positioned adjacent the grooves 21c or below the grooves 21c and within the bottom portion 21d of the wearable body. It should be understood that any
10 embodiment of the wearable bodies 21 may include a bottom portion that includes one or more projections or protuberances for mating within a hole or other aperture formed in a member 34 such as a sleeve segment, intermediate body, sleeve, or roller body.

15 The wearable bodies 21 are positionable within pockets 30 defined within the member 34 such as a sleeve, roller body, a segment 27 of a sleeve or other type of intermediate body. The size and shape of each pocket is defined by one or more walls 30a within the member having the pockets 30. A base portion of a segment of a sleeve, a sleeve body that is unitarily formed or other type of
20 intermediate body that is attachable to a roller body may have such pockets. As another example, the pockets 30 could be defined by one or more walls 30a formed within the roller body itself for facilitating direct attachment between the wearable bodies and the roller body. The one or more walls 30a may be configured to receive a particularly shaped wearable body. For instance, the one
25 or more walls 30a of each pocket may include one sidewall for receiving a cylindrical or rounded wearable body or may include multiple sidewalls to receive a polygonal shaped wearable body.

The pockets 30 that are formed within the member may also include a first
30 recess defined by one or more walls 30a and a second recess defined by walls 30b. The walls 30b defining the second recess may define a trough within the member 34 that has a bottom surface that is positioned higher, or more outward, relative to the bottom surface of the first recess defined by one or more walls 30a

(e.g. walls 30b may be shorter than walls 30a). In some embodiments, the plateau may be shaped differently than the shape of the first recess defined by one or more walls 30a. For instance, as may be seen from Figure 13, each pocket 30 may be shaped to include a first recess having a deep central circular shaped opening and at least one second recess that is shallower than the first recess and is rectangular in shape to help lock rotational movement of a wear boy that is also positioned within the circular first recess. The second recess may provide improved axial support to help resist forces that act on the wearable bodies in an axial direction to ensure the wearable bodies stay in position. Additionally, the second recesses defined by walls 30b may provide rotational resistance to prevent loosening or rotation of the wearable bodies during comminution operations.

Within the bottom of each pocket 30, a central aperture such as a channel 31 may be formed so that the channel or other aperture has an upper mouth that is in communication with the opening defined by the pocket walls 30a. The central channel 31 or other aperture may be elongated and be sized to receive a fastener 28 such as a bolt or screw. The inner wall of the channel 31 that defines the channel 31 may have threads formed thereon to mate with threads on the fastener 28 for facilitating attachment of the fastener within the channel 31.

The pockets 30 and wearable bodies 21 permit crushing bodies to be designed with wearable surfaces that are specifically configured to meet a particular comminution design objective. For example, each wearable body may have a particular composition so that it has a particular level of hardness or toughness so that the wearable body 21 wears at a particular rate during comminution operations of the crushing body 20. The rate of wear defined by the composition of each wearable body may define a wear pattern for the wear surface defined by the wearable bodies and aid in forming an autogenous layer of material on the wear surface during comminution operations. It is contemplated that the wearable bodies may be formed as powder metal parts or otherwise be constructed from a wide variety of material compositions and strengths. For instance, the wearable bodies may each be composed of a type of metal, with

some wearable bodies being of a stronger or harder metal than other wearable bodies. As another example, the wearable bodies 21 may be formed of a first metal structure having a composition such as steel and include a second metal structure 36 having another composition, such as a tungsten carbide tubular structure, cylindrical structure, or other body attached within, positioned within or
5 formed within that wearable body.

As noted above, the wearable bodies may have any of a number of different profiles for facilitating material draw, crushing, shearing, limiting axial material
10 flow, and packing of the autogenous layer of material being comminuted by the crushing body 20. The wearable bodies 21 may populate the entire roll surface or crushing surface of a roller 3 by being attached within the pockets 30 defined in a sleeve, sleeve segment, intermediate body, or directly within the roller body 19 such that there is no intermediate body or sleeve needed or used.

15 In some embodiments, wearable bodies may be configured to define edge protection as well. For instance, as shown in Figure 13, wearable bodies adjacent the edges of the crushing body may be configured to mate with a lip defined on each edge of a sleeve, roller body, or other member. The bottom of these wearable bodies may have an aperture sized and configured to receive
20 this lip or other structure. The lip may include one or more steps of differing heights to help facilitate location and interlocking between the member and these wearable bodies.

It should be appreciated that the wearable bodies may be arranged to define a
25 particular pattern of wear on the wear surface to facilitate formation of an autogenous layer of material during comminution of material operations. For example, the wearable bodies may be arranged in different columns of wearable bodies that extend circumferentially around the crushing body (e.g. in a direction C around the lateral or curved surface area of the crushing body) in a column of
30 wearable bodies that have wearable bodies aligned in series about a circumference of the crushing body 20.

For instance, the crushing body 20 may include a first column 41, a second

column 45 and a third column 49 of wearable bodies as may be seen in Figure 14. The first column 41 of wearable bodies may be adjacent a first end of the crushing body 20 and the third column 49 of wearable bodies may be adjacent the second end of the crushing body 20 that is opposite the first end. The
5 second column 45 of wearable bodies may be between the first and third columns 41, 49. For instance, the second column may extend circumferentially around the crushing body along a middle portion of the crushing body.

The first column 41 of wearable bodies may be of a composition of metal that is
10 harder or softer than the metal composition of the wearable bodies of the second column 45 of wearable bodies. The third column 49 of wearable bodies may also be of a composition of metal that is harder or softer than the metal composition of the wearable bodies of the second column 45 of wearable bodies. The metal composition of the third and first column of wearable bodies may be the same or
15 be within the same hardness range or toughness range that is harder or softer than the hardness range or tougher or less tough than the toughness range of the second column 45 of wearable bodies.

Of course, more than three columns of wearable bodies or less than three
20 columns of wearable bodies may be positioned circumferentially along the crushing body 20. For example, the crushing body 20 may also include a fourth column 43 of wearable bodies and a fifth column 47 of wearable bodies that extend in series circumferentially along the crushing body 20 at different sections. The fourth column 43 of wearable bodies may be located between the
25 first 41 and second 45 columns of wearable bodies and the fifth column 47 may be between the second 45 and third 49 columns of wearable bodies. The material composition of the wearable bodies in the fourth and fifth columns 43, 47 may be about the same or be the same so that the hardness, toughness or strength of those wearable bodies are within the same ranges. The wearable
30 bodies of the fourth and fifth columns 43, 47 may have the same range of strength, toughness or hardness as the wearable bodies in the first and third columns or have a range of strength, toughness or hardness that is of lower values or higher values as compared to the wearable bodies of the first and third

columns 41, 49. It should be understood that the wearable bodies of the fourth and fifth columns 43, 47 may have compositions such that they have larger or lower hardness, toughness or strength properties as compared to the wearable bodies of the second column 45 of wearable bodies.

5

It is also contemplated that the wearable bodies of different columns have different heights so that they extend to different distances away from the roller body, sleeve, sleeve segment, intermediate member or other member to which they are attached. For instance, the wearable bodies of the first and third
10 columns 41 and 49 may be taller or shorter than wearable bodies of the second column 45. The wearable bodies of the fourth and fifth columns 43 and 47 may also be taller or shorter than the wearable bodies of the first, second, and third columns 41, 45 and 49.

15

It is further contemplated that the wearable bodies of different columns may have different outer surface profiles, peripheral shapes, perimeters, lengths, widths, outer surface textures, outer surface patterns, or types of protuberances so that they may better compensate for different pressure curve profiles along an axial width of a crushing body 20. Changes of one or more of the above wearable
20 body characteristics as a function of position on a crushing body 20 such as a roller body, sleeve, sleeve segment, intermediate member or other member, may better maintain autogenous layer at all surface portions of a crushing body, create a more uniform autogenous layer, or improve wear performance.

25

For instance, in one particular non-limiting example, the wearable bodies of the first and third columns 41 and 49 may comprise a network of grooves which are more tightly interconnected, more relatively spaced, deeper, shallower, wider, narrower, more tapered, less tapered, greater in number, or lesser in number than a network of grooves provided to wearable bodies located in the second
30 column 45. The wearable bodies of the fourth and fifth columns 43 and 47 may also be more tightly interconnected, more relatively spaced, deeper, shallower, wider, narrower, more tapered, less tapered, greater in number, or lesser in number than a network of grooves provided to wearable bodies of any one or

more of the first, second, and third columns 41, 45 and 49. The wearable bodies of the fourth 43 and fifth 47 columns may have different outer surface profiles, peripheral shapes, perimeters, lengths, widths, outer surface textures, outer surface patterns, or types of protuberances, than wearable bodies of any one or
5 more of the first, second, and third columns 41, 45 and 49. Where used herein, the term "groove" may comprise one or more channels, recesses, pockets, dimples, valleys formed between adjacent ridge portions or protuberances, blind apertures, or through-apertures, without limitation.

10 In some preferred embodiments, a network of grooves provided to wearable bodies may be fewer in number, wider, deeper, and/or more displaced in center portions of the crushing body 20 (e.g., second column 45) than wearable bodies provided to more lateral portions of the crushing body 20 (e.g., first and third columns 41 and 49). In some preferred embodiments, fourth and fifth columns
15 43 and 47 may be provided with a network of grooves having an intermediate pattern which blends a more tightly-spaced network of grooves in the first and third columns 41 and 49 with the more displaced network of grooves in the second column 45. In some embodiments, functionally-graded spacings of grooves along a crushing body may be directly etched into the substrate of a
20 crushing surface without the use of separable and independently-attached wearable bodies.

For example, turning now to FIGS. 12A-12D, a functionally-graded pattern of grooves may be provided along a length or width of a crushing body surface. In
25 some preferred embodiments, as shown in FIG. 12D, the grooves may be more displaced or less populous in central regions of a crushing body 20, and the grooves may be more tightly interconnected or more populous at side/end portions of a crushing body. One or more regions 43, 47 provided between the central regions 45 of the crushing body and the side/end regions 41, 49 of the
30 crushing body may have grooves which are provided to *blend* the groove patterns between the central region and side/end regions. The regions 43, 47 may provide a compromise of moderately spaced grooves - each being spaced a

distance from each other which is less than the central regions, but more than the side/end regions of the crushing body 20.

Such patterns may be formed by providing a number of wearable bodies 21b, 21b', 21b" each including multiple grooves 21c, 21c', 21c" formed in a top portion of the crushable body 20 or other wearable surface to facilitate retaining comminuted material. The bottom portion 21d, 21d', 21d" of each wearable body 21b, 21b', 21b" may include a cylindrical projection that defines a central opening or channel through which a fastener may pass. The head of the fastener may be positioned adjacent the grooves 21c, 21c', 21c" or below the grooves 21c, 21c', 21c" and within the bottom portion 21d, 21d', 21d" of the wearable body. It should be understood that any embodiment of the wearable bodies 21b, 21b', 21b" may include a bottom portion that includes one or more projections or protuberances for mating within a hole or other aperture formed in a member 34 such as a sleeve segment, intermediate body, sleeve, or roller body. A width, length, depth, shape, number, or arrangement of grooves 21c, 21c', 21c" may vary between wearable bodies 21b, 21b', 21b".

In some embodiments, the widths W, W', W" of the grooves 21c, 21c', 21c" in the wearable bodies 21b, 21b', 21b" may change along a length of a crushing body as shown in FIG. 12D. In some embodiments, the number of grooves 21c, 21c', 21c" in a wearable body 21b, 21b', 21b" may change along a length of a crushing body as shown in FIG. 12D. For instance, the number of grooves 21c, 21c', 21c" may be higher in the side/end regions of the crushing body 20 than in central regions 45. In some embodiments, the depths D, D', D" of the grooves 21c, 21c', 21c" in the wearable bodies 21b, 21b', 21b" may change along a length of a crushing body 20. In some embodiments, the area A, A', A" or shape of protuberances extending from the wearable bodies 21b, 21b', 21b" may change along a length of a crushing body 20, as a function of its axial position on a crushing body. One or more of the aforementioned characteristics of a wearable body 21b, 21b', 21b" may, for example, change as a function of location along an axial width of a crushing body 20 -- particularly in relation to a center 45 or side/end region 41, 49. For example, an area A" of a protuberance

located adjacent a side/end region 41, 49 of the crushing body 20 may be smaller than an area A of a protuberance located adjacent a central region 45. In another example, an area A' of a protuberance adjacent bands 43 and 45 may be less than an area A of a protuberance provided adjacent a central region 45
5 and may be greater than an area A" of a protuberance located near side/end regions 41, 49.

As may be appreciated from Figures 15-17, embodiments of the crushing body 20 may be configured so that wearable bodies 21d are attached directly to a
10 member 34 that is a roller body 19. Edge protection elements may also be attached to the member 34. The member 34 that is the roller body 19 may be composed of metal such as a type of steel suitable for a comminution application and include a plurality of channels 31 or other types of holes or apertures for receiving fasteners 28 for attaching the wearable bodies 28 along a surface of
15 the member 34. Each wearable body 21d may include one or more grooves 53 or other apertures on one or more sides of the wearable body 21d that are sized and shaped to receive protuberances or projections 51 that extend from other sides of other wearable bodies immediately adjacent to that wearable body. A central opening or channel 57 may be defined within the wearable body for
20 receiving a portion of a fastener 28 that extends from the wearable body to a member 34 for attaching the wearable body to the member 34. The fastener 28 may be threaded and mate with threads in channel 31 for attaching the wearable body 21 to the member 34, which may be a roller body 19 for example. The fastener 28 may also be threaded so that it mates with threads in channel 57.

25 The head ends 28a of the fasteners 28 may be positioned in a middle or bottom portion of the wearable body within the channel 57 so that the fastener would not come into contact with any material to be crushed by the crushing body 20. A substantial part of the height of the wearable body that extends from the member
30 34 to define the wearable surface of the crushing body may then protect the fastener from being affected by comminuted material during crushing operations. A plug 60 such as an insert, filler material, or a metal element may be inserted within the channel 57 to cover the fastener adjacent the outer surface of the

wearable body. For instance, an insert that is composed of tungsten carbide or carbide may be inserted within the channel 57 above or over the head end 28a of the fastener 28 to cover the head end 28a of the fastener. The insert or other type of plug may then help protect the fastener from being damaged during
5 comminution operations.

The plug could alternatively include a filler material, or include epoxy or other adhesive that is positioned in contact with the head end 28a of the fastener. For some embodiments, the plug may include both an adhesive such as an epoxy
10 and an insert. For example, the plug may include adhesive that engages with and is adjacent the head end 28a of the fastener 28 and an insert that is in contact with the adhesive and is over the head end 28 of the fastener. The insert may extend to a position adjacent the outermost end of the wearable body (e.g. is flush with the outermost surface of the wearable body or is slightly recessed or
15 extended relative to this outermost surface) or may extend out of the wearable body so that one end of the insert is out of the wearable body and one end is within the channel 57.

The bottom portion of the wearable bodies 21d may be angled or tapered to
20 engage with angled or tapered walls 30a that define pockets, channels, recesses, grooves, or other apertures for receiving the wearable bodies. The tapered walls 30a and bottom portion of the wearable bodies may engage with each other to provide a desired interference fit and induce friction to help prevent the wearable bodies from becoming loosened during comminution operations.
25 An adhesive or other material may also be included within the pockets or other type of aperture to help facilitate attachment of the wearable bodies 21 to the member 34 positioned within the pockets 30.

Referring to Figures 18-21, the wearable bodies may be sized and configured to
30 include multiple inserts within one wearable body. As noted above with reference to Figures 15-17, the inserts may jut out of the wearable bodies beyond an outermost end or outermost side of the wearable bodies that is opposite the innermost side or innermost end of the wearable bodies positioned adjacent

member 34, which may be a sleeve, a sleeve segment, or a roller body, for example. The inserts 60b may be positioned within a central channel and cover a head end 28a of a fastener that extends from the wearable body to the member 34. Epoxy or other type of adhesive material 60a or filler material may be positioned in contact with the head end of the fastener and be positioned between the head end 28a and the insert 60b. Examples of filler material may include one or more types of metal, a plastic cap or other type of filler composed of polymeric material, an alloy, or other filler material suitable to meet a particular design objective. It should be understood that the adhesive material 60a may help attach the insert 60b to the wearable body 21 and that the insert may help protect the fastener from damage that could result from comminution operations as the insert and outer portions of the wearable body will cover the fastener and protect it from material being comminuted and forces directly applied to the outermost layer of the wear surface and material being comminuted during comminution operations.

The wearable bodies 21 may also include one or more large projections 64 that are insertable or receivable within large holes 37 within the member 34. The large holes 37 and projections 64 may help facilitate connection of the wearable bodies to the member 34. Adhesives or other fastening mechanism may be utilized to facilitate attachment of the projections 64 to the member 34.

The wearable bodies may be elongated in one direction to define a length. The length of each wearable body may then be attached to the member 34 so that the length extends circumferentially along a portion of the member 34 (e.g. extends in direction C along a lateral surface area portion or curved surface area portion of the crushing body). The surface of the member 34 may also have a profile mating with a bottom profile of the wearable members to facilitate attachment of the wearable member 34. For instance, a plurality of rails 42 may be defined on the member 34 and the bottom of the wearable members may define a groove 65 in which one or more projections are located that is shaped to receive a portion of a rail on the member when the projections are mated within the holes 37 sized to receive those projections 64. The rails 42 and holes 37 and

projections 64 may function to help facilitate locating where a wearable member is insertable or attachable to the member 34. The shape of the groove 65 and rail may also help induce friction upon movement of a wearable member to increase the strength of attachment and prevent the wearable members from becoming loose during comminution operations.

Referring to Figures 22-23, embodiments of the crushing body 20 may be configured so that a plurality of separate intermediate members 87 are attached to a roller body 19 and also to wearable bodies 21e to attach the wearable bodies to the roller body to form the crushing body 20. The length of the wearable bodies 21e may be elongated along their length and be positionable so that the length of the wearable bodies extends across the width W of the crushing body. The wearable bodies 21e may include a plurality of inserts positioned therein. The inserts may each be positioned within a respective channel formed in the wearable body 21e. A respective fastener 28 may be within a respective one of the channels of the wearable body 21e and extend from that wearable body 21 to the intermediate member 87. One or more than one intermediate member 87 may be positioned adjacent the wearable bodies 21 and roller body 19 or alternatively may be adjacent a sleeve member or sleeve segment for facilitating the attachment of the wearable bodies.

For example, the intermediate bodies may have an outer side and a lower side and be tapered as they extend from an inner side to an outer side. The inner side of each intermediate member 87 may be positioned within a respective hole or aperture of a roller body 19 or other member. The outer side of the intermediate member 87 may be positioned in a bottom aperture or groove formed in the wearable body to receive the outer side of the intermediate member. Adhesive such as epoxy or welding may also be used to help facilitate attachment of the intermediate members 87 to the roller body 19 or other member and the wearable member 21. Fasteners 28 may extend from the wearable bodies to the intermediate member 87 as well. Each fastener 28 may be positioned within a respective channel 82 of the wearable body and have a tail end extend into the intermediate member 87 to attach the wearable body to

the intermediate body. As may be appreciated from the fastener 28 shown in broken line in Figure 23, the head end of the fastener may be located within a middle portion of the wearable body and be covered by an insert, filler, or other plug element 111. The tail end of the fastener may extend into the intermediate member 87.

In other alternative embodiments, it is contemplated that the intermediate member 87 may have one or both of its sides configured to have openings for mating with one or more projections extending from the wearable bodies 19 or roller body 19 or other member to facilitate attachment of the intermediate members 87 to the wearable bodies and roller body or other member. For instance, an inner side of the intermediate body 87 may have openings for receiving projections from a roller body and the outer side may have projections for insertion into apertures of the wearable body. As another example, the inner side of the intermediate body may have apertures for receiving protuberances of a roller body and the outer side of the intermediate body may have apertures for receiving projections from a bottom side of a wearable body to facilitate attachment of the intermediate body to those structures.

Figure 24 is a cutaway view looking through a center portion of a crushing body according to some embodiments. Referring to Figure 24, embodiments of a crushing body may be configured so that one or more intermediate members 87' are removably attached to a roller body 19'. As shown, intermediate members 87' may be integrally attached to wearable bodies 21', 21'', 21''', 21'''' to secure the wearable bodies to the roller body 19' to form the crushing body. The length of each wearable body 21', 21'', 21''', 21'''' may vary, and each wearable body 21', 21'', 21''', 21'''' may or may not have a similar length. The wearable bodies 21', 21'', 21''', 21'''' may be positionable so that their total combined length (determined by the cumulative lengths of each wearable body 21', 21'', 21''', 21''') extends approximately the width W of the crushing body. As shown, the wearable bodies 21', 21'', 21''', 21'''' may include a plurality of grooves 82', 82'', 82''', 82'''' positioned therein. Respective ones of the grooves 82', 82'', 82''', 82'''' of each wearable body 21', 21'', 21''', 21'''' may be positioned and/or configured

to extend with a wearable body 21 so as to optimize autogenous layer generation or maintenance, protect the one or more integral intermediate members 87', and/or protect portions of the roller body 19'. The one or more intermediate members 87' may be positioned adjacent the wearable bodies 21', 21'', 21''', 21''''
5 and roller body 19' or alternatively may be adjacent a sleeve member or sleeve segment for facilitating the attachment of the wearable bodies.

For example, the intermediate members 87' may be tapered as they extend towards an outer side. They may be localized with respect to a wearable body,
10 or they may extend an entire length of a wearable body. Intermediate members 87' may be provided symmetrically or asymmetrically about a wearable body. The inner side of each intermediate member 87' may be permanently joined to or otherwise form an integral portion of a wearable body. The outer side of the one or more intermediate members 87' may be positioned in a bottom aperture or
15 groove formed in the wearable body to receive the outer side of the intermediate member. Adhesive such as epoxy or welding may also be used to help facilitate attachment of the intermediate members 87' to the roller body 19' or other member and the wearable bodies 21', 21'', 21''', 21'''. While not shown in Figure 24, fasteners 28 may extend from the wearable bodies 21', 21'', 21''', 21'''' to the
20 roller body 19' or to one or more recesses, grooves, or other apertures 34' formed within the roller body 19'.

As may be appreciated from Figure 24, the grooves 82', 82'', 82''', 82'''' may change in size, shape, pattern, quantity, texture, variation, depth, width, length,
25 degree of taper, angle, orientation, or other characteristic - depending on the respective location of a groove 82', 82'', 82''', 82'''' in relation to the roller body 19'. For example, as shown, wearable bodies 21', 21'', 21''', 21'''' which are more centrally located to a central portion of a crushing body may comprise grooves 82' which differ from grooves 82'''' provided closer to an end of a roller body 19'.
30 In some preferred embodiments, a distance d_1 between nearest neighboring grooves 82', 82'' may be largest adjacent middle or central portion of a roller body 19'. In some preferred embodiments, a distance d_2 between nearest neighboring grooves 82'', 82''' (which are located further from the central portion

of a roller body 19') may be smaller than the distance d_1 . In some preferred embodiments, a distance d_3 between nearest neighboring grooves 82'", 82'" (which are located even further from the central portion of a roller body 19') may be smaller than distances d_1 and d_2 . In some preferred embodiments, distances
5 (e.g., d_3 , d_4) between nearest neighboring grooves 82''', 82'''' (which are located adjacent side/end regions of a roller body 19') may be the smallest found on the roller body 19'.

In some instances, wearable bodies 21', 21'', 21''', 21'''' may increase or
10 decrease in hardness or gradually change in mechanical material properties (e.g., ductility) along a length of a crushing body. For example, in central regions of a crushing body, where higher pressures are generally seen, a harder robust material may be used, and in side/end regions, where pressures are generally less, a softer material may be used to form wearable bodies 21', 21'', 21''', 21''''.

15 In regions between side/end regions and central regions, wearable bodies may comprise yet different material compositions. For example, a moderate hardness material may be used. Referring to Figure 25, a crushing body may include a member such as a sleeve or roller body that has multiple sets of wearable bodies. The different sets of wearable bodies may be within the same column of
20 wearable bodies that extend circumferentially along the curved surface area of the member 34. For instance, the wearable bodies 21 may include a first column 103 and a second column 104 of wearable bodies that each includes a first set 100 of wearable bodies and a second set 101 of wearable bodies. The first set 100 of wearable bodies may be positioned within recesses, grooves, or other
25 apertures formed within the member 34, such as a roller body or sleeve or sleeve segment. The second set 101 of wearable bodies may be positioned on a lip, trough, or plateau 121 defined by the member 34 between adjacent recesses, grooves, or other apertures. The depth of the lip, trough, or plateau 121 within the member 34 may be shallower than the depth of the recesses, grooves, or
30 other apertures in which the first set of wearable bodies are positioned.

The second set 101 of wearable bodies may be attached to the member via fasteners 28. The fasteners may be positioned within channels or other

apertures of the wearable bodies and extend into the member to attach those wearable bodies to the member 34. The fasteners may be positioned within the channel so that it is well within the channel or has a head end that is recessed below the outermost side of the wearable body or may alternatively be flush with
5 the outermost side of the wearable body.

The wearable bodies of the first and second sets 100 and 101 may be arranged so that the wearable bodies extend circumferentially in series and wearable bodies of the first and second sets 100 and 101 alternate one after the other
10 along the column such that a wearable body of the first set 100 is immediately adjacent on opposite sides with wearable bodies of the second set 101 as the column of wearable bodies extends along the circumferential direction of the member 34. For instance, the first side 115 of a wearable body of the first set 100 may face toward a circumferential direction and face toward or engage a first
15 side of a wearable body of the second set 101 of wearable bodies. The second side 116 of that wearable body of the first set 100 may face toward the opposite side and thereby face toward or engage a second side of a wearable body of the second set 101 of wearable bodies.

20 The bottom portions of the wearable bodies of the first set 100 of wearable bodies may be tapered to be wider and have sidewalls for engaging, interlocking with, or touching the sidewalls of immediately adjacent wearable members of the second set 101 of wearable members. The wearable members of the second set of wearable member may have sidewalls that complement the sidewalls of the
25 immediately adjacent wearable members of the first set of wearable members so that it engages, touches, or interlocks with those wearable members. The sidewalls may be tapered for example so that sidewalls of the wearable bodies in the first set 100 are inclined or declined and the sidewalls of the wearable bodies of the second set of the other of the inclined or declined to permit interlocking fits
30 between the wearable bodies of the different sets 100 and 101 of wearable bodies.

The wearable bodies of the first and second sets 100 and 101 may also include profiles such as grooves 119 and protuberances 117 to facilitate interlocking of immediately adjacent wearable members within the same column of wearable bodies. For instance, the wearable members of the first set 100 may include
5 grooves 119 and the wearable bodies of the second set 101 may include protuberances 117 or projections for fitting within the grooves 119 to facilitate interlocking. The interlocking may be configured to permit some looseness (e.g. not be an interference fit) due to manufacturing tolerances and may also be loose to facilitate the use of an adhesive therein to help further facilitate
10 interconnection or attachment between the immediately adjacent wearable bodies. Alternatively, it is contemplated that the interlocking between immediately adjacent wearable bodies may provide interference fits between immediately adjacent wearable bodies.

15 Additionally, the wearable bodies may have sides that face toward wearable bodies of an immediately adjacent column of wearable bodies configured to interlock with, touch, or engage those wearable bodies as well. For instance, as with other embodiments discussed above, the wearable bodies could include protuberances and grooves, inclined or declined sides, or other elements for
20 mating with, contacting, or interlocking with wearable members of the immediately adjacent column of wearable members. It should be understood that the members of the immediately adjacent column may have sides that are shaped to complement with such a profile to facilitate the interlocking, engagement, or touching of the sides as well.

25 It should be understood that the wearable bodies for the above referenced embodiments of crushing bodies may be positioned adjacent to other immediately adjacent wearable bodies so that there is a minimally small gap or no gap or other opening between immediately adjacent wearable bodies. The
30 wearable bodies may all touch, engage or interlock with immediately adjacent other wearable bodies so that a wear surface is defined by all the wearable bodies and covers a sleeve, roller body or other member of the crushing body.

It should be appreciated that the positionability of the wearable bodies and use of fasteners for attaching the wearable bodies provide a number of advantages. For instance, surfaces on roller press and vertical mills that are grinding clinker or even harder material are often worn unevenly across the width W of a roller.

5 This requires frequent resurfacing of the roller before the entirety of the wear surface is expended, and is very time consuming and costly, and often the result is unwanted down time. Embodiments of a crushing body utilizing wearable bodies attached via one or more fasteners as disclosed herein can permit a roller surface to have different patterns of hardness for different applications to permit
10 the wear surface to wear evenly.

Further, if a surface gets damaged, it would be possible to only change the damaged part of the roller and not the whole roller. For instance, only damaged wearable bodies would need to be removed and replaced. The entire roller
15 surface or sleeve of a roller would not need repairing, which can reduce downtime for maintenance of the roller or other type of crushing body. For instance, instead of resurfacing by welding or changing the rollers entirely, only the worn wearable bodies could be changed or altered to accommodate the actual wear pattern on the rollers. Such changing of worn wearable bodies may
20 occur in situ and permit the roller to be back in operation with minimal downtime. It may also be possible to permit a re-arranging or fine tuning of the configuration of wearable bodies for defining the wear surface to alter the wear characteristics of the crushing surface to better accommodate comminution of a particular material that device may be used to comminute.

25 Thus, embodiments of the crushing body can help minimize down time of a crushing device by permitting limited maintenance operations to be performed so that only the part of a wearable surface that is damaged or subject to excessive wear needs be changed or remedied. It is also possible to make a surface with
30 different hardness patterns to accommodate different grinding situations or to retrofit different crushing bodies at later times to accommodate different grinding or comminution operations. This can be especially relevant in the mining industry where ores have different properties and toughness.

It should be appreciated that embodiments of rollers and other types of crusher bodies or crushing bodies may be made using a number of different insert arrangements within the scope of the claimed invention. Additionally, the material
5 selected for use in the wearable bodies, plugs, sleeves, or roller body could be any of a number of material choices found suitable to meet particular design criteria. As another example, embodiments of the rollers, sleeves for rollers, and other types of crushing bodies may be sized to have any of a number of diameters or wear surface widths for meeting a particular design objective. As
10 yet another example, the size, shape, and composition of the wearable bodies may be any of a number of different sizes, shapes and compositions to meet a particular design objective. As yet other examples, embodiments of the crushing bodies may have any of a number of shapes and sizes. For instance, some embodiments of the crushing bodies may be sized and shaped as tables 5 or as
15 a wear surface for attachment to a table or anvil of a mill or other crushing device.

While certain present preferred embodiments of crushing devices, a crushing body for use in a crushing device and certain embodiments of methods of
20 practicing the same have been shown and described, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practiced within the scope of the following claims.

CLAIMS

1. A crushing body for a crushing device, the crushing body having a crushing surface that is sized and shaped to facilitate comminution of material when the crushing body is moved, the crushing body comprising:
- at least one first member having a first end, a second end opposite the first end, and a width extending from adjacent to the first end of the at least one first member to adjacent to the second end of the at least one first member;
- a plurality of wearable bodies attached to the at least one first member and arranged along the width of the at least one first member to define the crushing surface, each wearable body having a wearable body characteristic, each wearable body characteristic relating to at least one of an outer surface profile, a peripheral shape, perimeter, length, width, an outer surface texture, an outer surface pattern, a type of protuberance, groove density, groove depth, groove width, an amount of taper, a number of grooves, or a mechanical material property of the respective wearable body;
- wherein at least two of the plurality of wearable bodies comprise different wearable body characteristics.
2. The crushing body of claim 1 wherein the crushing body is a roller, a wear surface for a table or a wear surface for an anvil and wherein the crushing device is a mill, roller mill, roller press, vertical roller mill, or vertical mill.
3. The crushing body of claim 1 wherein the wearable bodies cover an entirety of an outer surface of the at least one first member to which those wearable bodies are attached for defining the crushing surface of the crushing body.
4. The crushing body of claim 1 wherein the at least one first member is comprised of a plurality of first members, each of the first members being connected together to form a sleeve that is sized for attachment to a roller body.
5. The crushing body of claim 1 wherein the wearable bodies are first wearable bodies and the crushing body is comprised of a first column of wearable bodies

that extend circumferentially along a curved surface area of the at least one first member, the wearable bodies of the first column of wearable bodies comprising the first wearable bodies and second wearable bodies, the first column of wearable bodies extending so that the wearable bodies extend circumferentially
5 in series and the first wearable bodies and second wearable bodies alternate one after the other along the first column such that each of the first wearable bodies is immediately adjacent on opposite sides with second wearable bodies; each of the first wearable bodies being positioned in a first recess within the at least one first member and each of the second wearable bodies being positioned
10 in a second recess within the at least one first member, a depth of the first recess being deeper or shallower than a depth of the second recess; and wherein there are no fasteners extending from the second wearable bodies to the at least one first member.

15 6. The crushing body of claim 1 wherein each of the fasteners is partially positioned within the channel of a respective one of the wearable bodies such that a head end of each fastener is positioned below an outer surface of the wearable body to which that fastener is attached and wherein the crushing body further comprises:
20 a plurality of plugs, each of the plugs being attached to a respective one of the wearable bodies within the channel of that wearable body such that the plug covers the fastener within that channel.

25 7. The crushing body of claim 6 wherein adhesive or filler material is positioned with the channel of each of the wearable bodies such that the adhesive or the filler material covers the head end of the fastener within the channel and engages the plug within that channel.

30 8. The crushing body of claim 1 wherein the at least one first member has a plurality of apertures defined therein, each of the apertures being shaped to receive a respective one of the wearable bodies; and

wherein the at least one first member has at least one opening in communication with each of the at least one aperture, each of the at least one opening sized to receive a portion of a respective one of the fasteners.

5 9. The crushing body of claim 1 further comprising a plurality of edge protection elements, the plurality of edge protection elements comprised of a first set of edge protection elements and a second set of edge protection elements, the first set of edge protection elements being positioned adjacent a first end of the crushing body and the second set of edge protection elements being positioned
10 adjacent a second end of the crushing body that is opposite the first end of the crushing body.

10. The crushing body of claim 1 further comprising a roller body and wherein the at least one first member is comprised of a plurality of intermediate
15 members, each of the intermediate members having a first side engaging the roller body and a second side engaging a respective one or more of the wearable bodies.

11. The crushing body of claim 1 wherein the fasteners are bolts.
20

12. The crushing body of claim 1 wherein the at least one first member has a plurality of rails defined thereon and a plurality of holes formed in the rails and wherein each of the wearable bodies has a first side that has a groove sized to receive a portion of a respective one of the rails and a projection sized to be
25 received within a respective one of the holes.

13. The crushing body of claim 1 wherein the channel is a first channel and the fasteners are first fasteners and each of the wearable bodies has at least one second channel and wherein the crushing body is further comprised of second
30 fasteners, each of the second fasteners being partially positioned within a respective one of the at least one second channel and extending from that second channel of the wearable body to the at least one first member to attach that wearable member to the first member.

14. The crushing body of claim 1 wherein the wearable members are arranged along a curved surface area of the crushing body in a plurality of columns, each of the columns extending circumferentially along the curved surface area of the crushing body, the columns comprising a first column of the wearable bodies, a second column of the wearable bodies and a third column of the wearable bodies;
the first column of wearable bodies being adjacent a first end of the crushing body;
the second column of wearable bodies being adjacent a second end of the crushing body that is opposite the first end;
the third column of wearable bodies being between the first and second columns of wearable bodies; and
the wearable bodies of the third column of wearable bodies having a different wearable body characteristic than the wearable bodies of the first and second columns of wearable bodies.

15. The crushing body of claim 14, wherein wearable bodies in the first and second columns of wearable bodies share a similar wearable body characteristic.

16. The crushing body of claim 14 wherein the columns of wearable bodies are also comprised of a fourth column of wearable bodies that is positioned between the first and third columns of wearable bodies and a fifth column of wearable bodies that is positioned between the second and third column of wearable bodies;
the wearable bodies of the third column of wearable bodies having a different wearable body characteristic than the wearable bodies of the fourth and fifth columns of wearable bodies;
the wearable bodies of the fourth column of wearable bodies having a different wearable body characteristic than the wearable bodies of the first column of wearable bodies; and

the wearable bodies of the fifth column of wearable bodies having a different wearable body characteristic than the wearable bodies of the second column of wearable bodies.

5

17. The crushing body of claim 16, wherein wearable bodies in the fourth and fifth columns of wearable bodies share a similar wearable body characteristic.

10

18. A crushing body for a crushing device, the crushing body having a crushing surface that is sized and shaped to facilitate comminution of material when the crushing body is moved, the crushing body comprising:

at least one first member having a first end, a second end opposite the first end, and a width extending from adjacent to the first end of the at least one first member to adjacent to the second end of the at least one first member;

15

wherein the crushing body comprises a pattern of grooves arranged along a curved surface area of the crushing body in a plurality of columns, each of the columns extending circumferentially along the curved surface area of the crushing body, the columns comprising a first column of grooves, a second column of grooves and a third column of grooves;

20

the first column of grooves being adjacent a first end of the crushing body;

the second column of grooves being adjacent a second end of the crushing body that is opposite the first end;

the third column of grooves being between the first and second columns of wearable bodies;

25

the wearable bodies of the third column of grooves having a different groove characteristic than the grooves of the first and second columns; the groove characteristic relating to at least one of a groove size, groove variation, groove angle, groove orientation groove profile, groove shape, groove texture, a groove length, an outer surface texture, groove pattern, groove density, groove depth, groove width, groove taper, relative groove spacing, or number of grooves;

30

wherein the first, second, and third columns define the crushing surface.

19. The crushing body of claim 18, wherein grooves in the first and second columns of grooves share a similar groove characteristic.

20. The crushing body of claim 18 wherein grooves in the third column of
5 grooves are wider, deeper, or fewer in number than grooves in the first and second columns of grooves.

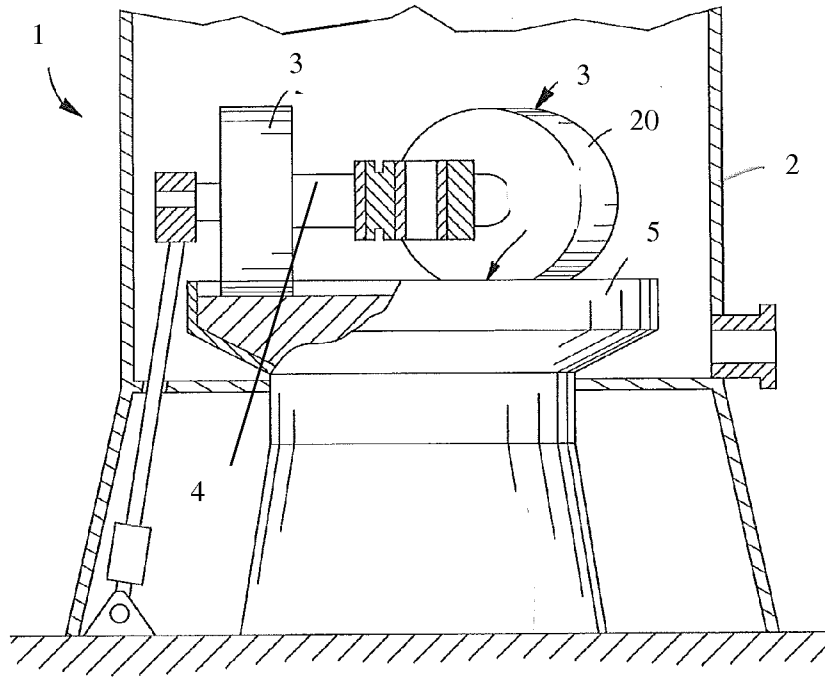
21. The crushing body of claim 18 wherein the columns of grooves are also
10 comprised of a fourth column of grooves that is positioned between the first and third columns of grooves and a fifth column of grooves that is positioned between the second and third column of grooves;
the grooves of the third column of grooves having a different groove
characteristic than the grooves of the fourth and fifth columns of grooves;
the grooves of the fourth column of wearable bodies having a different groove
15 characteristic than the grooves of the first column of grooves; and
the grooves of the fifth column of grooves having a different groove characteristic
than the grooves of the second column of grooves.

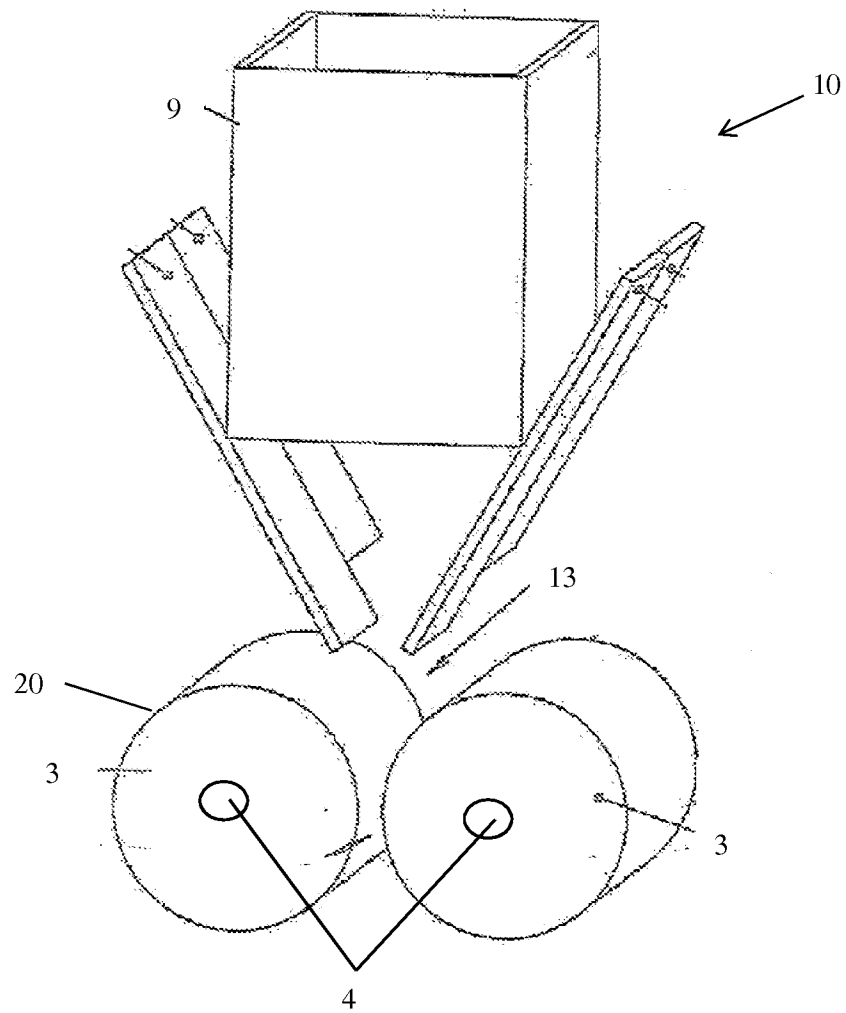
22. The crushing body of claim 21, wherein grooves in the fourth and fifth
20 columns of grooves share a similar groove characteristic.

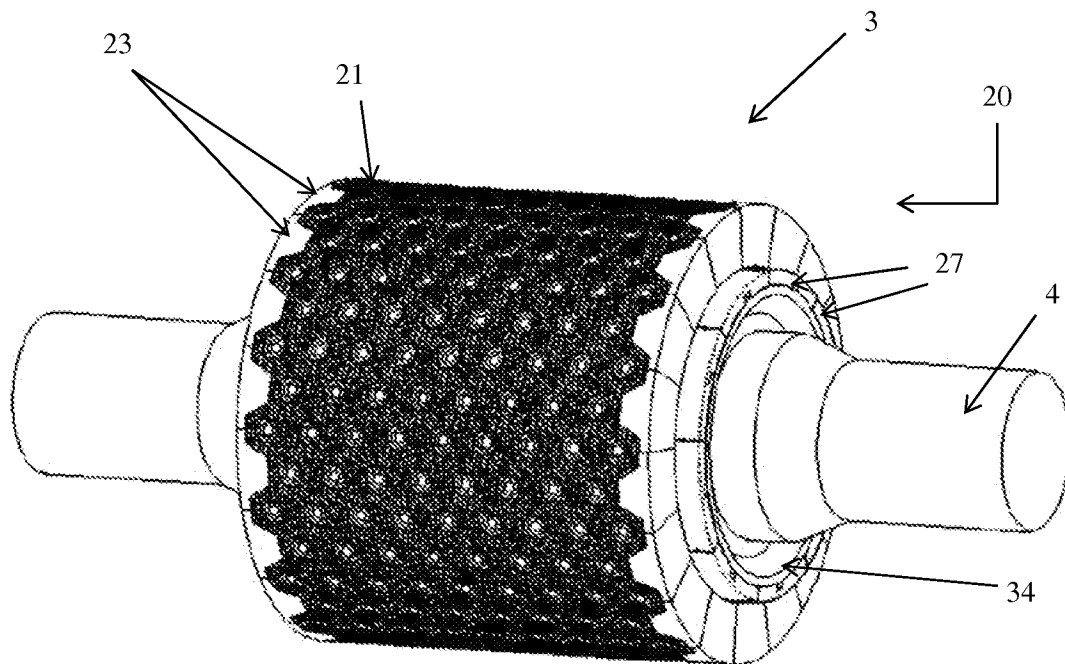
23. The crushing body of claim 21 wherein grooves in the fourth and fifth
columns of grooves are wider, deeper, or fewer in number than grooves in the
first and second columns of grooves.

25

30

**FIGURE 1**

**FIGURE 2**

**FIGURE 3**

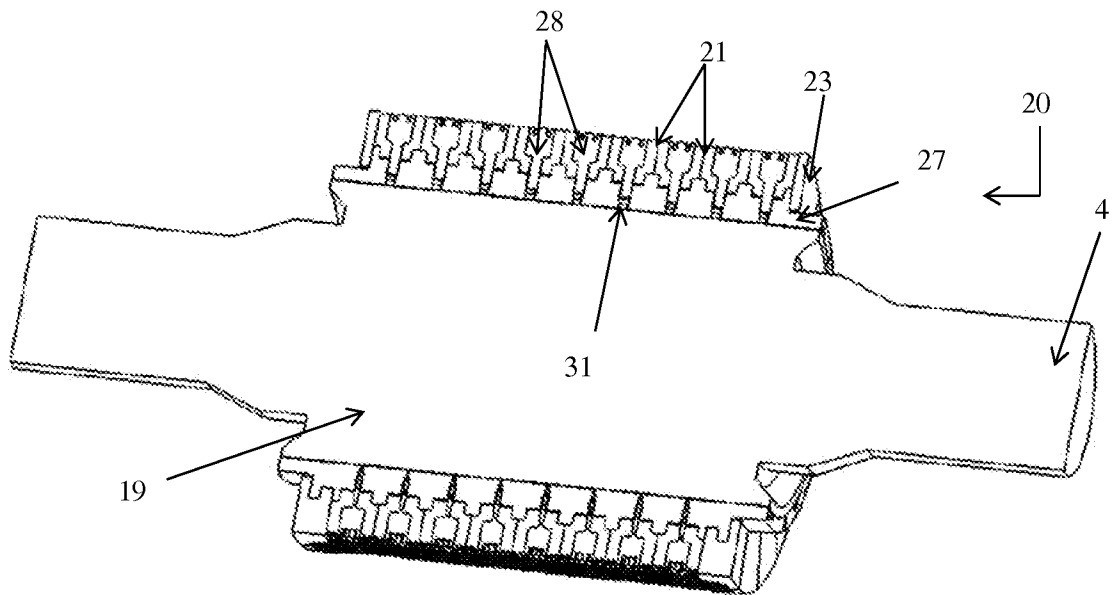
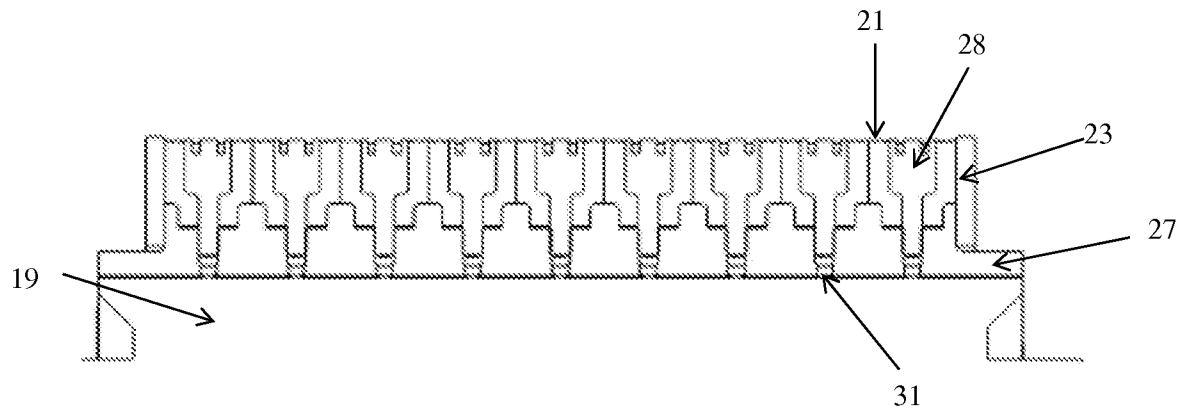
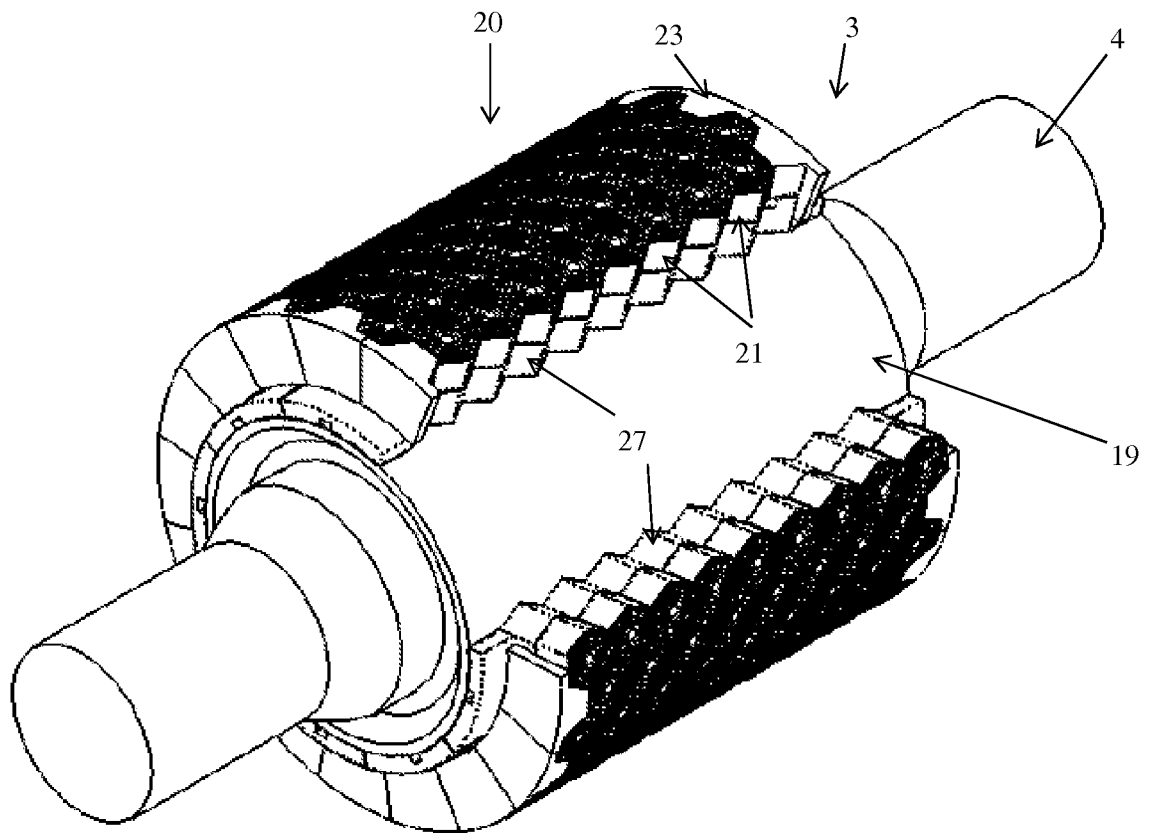
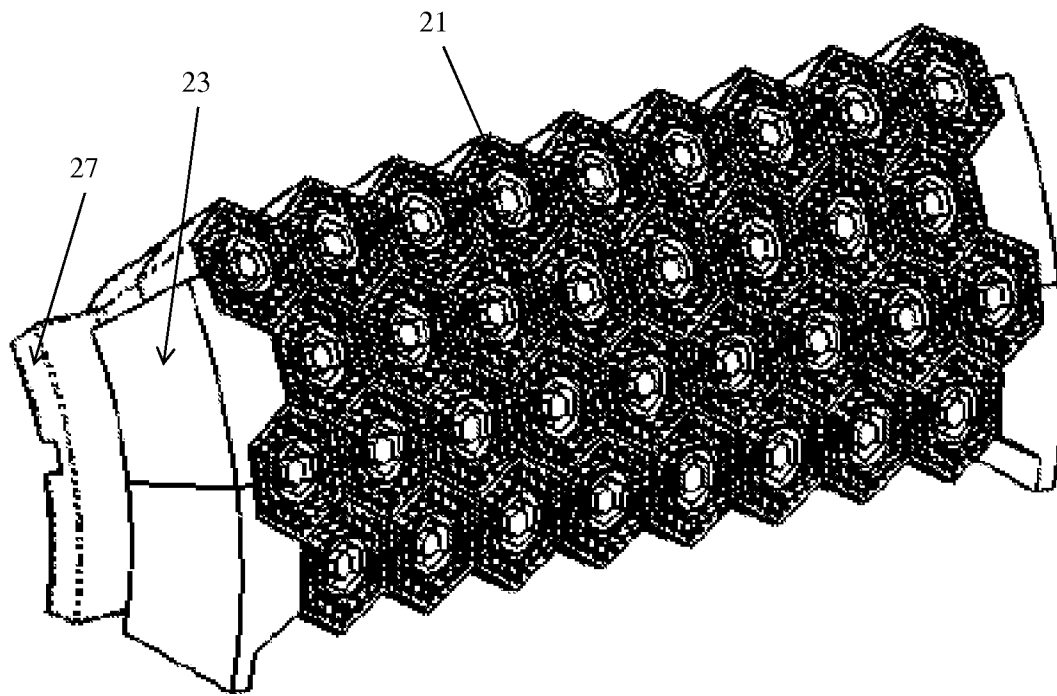


FIGURE 4

**FIGURE 5**

**FIGURE 6**

**FIGURE 7**

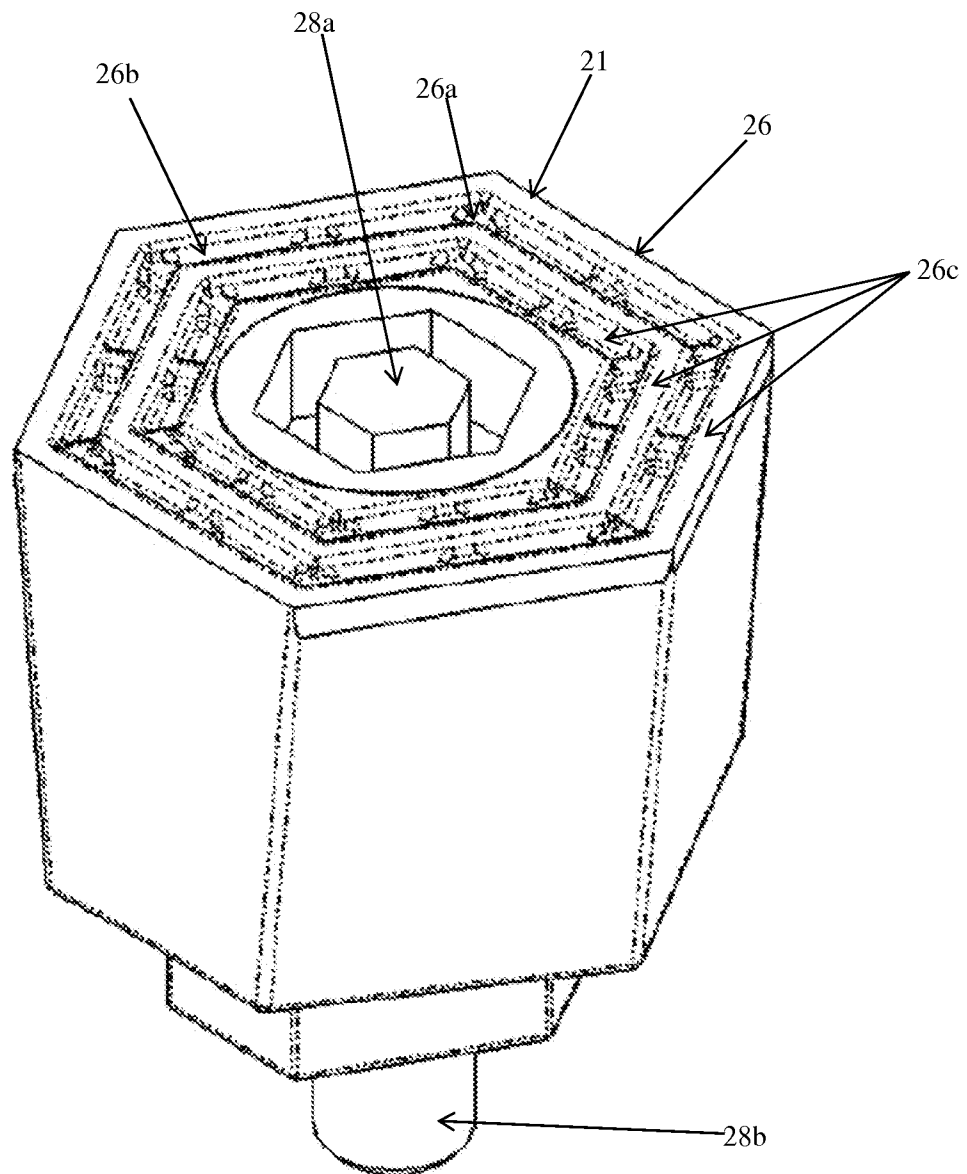
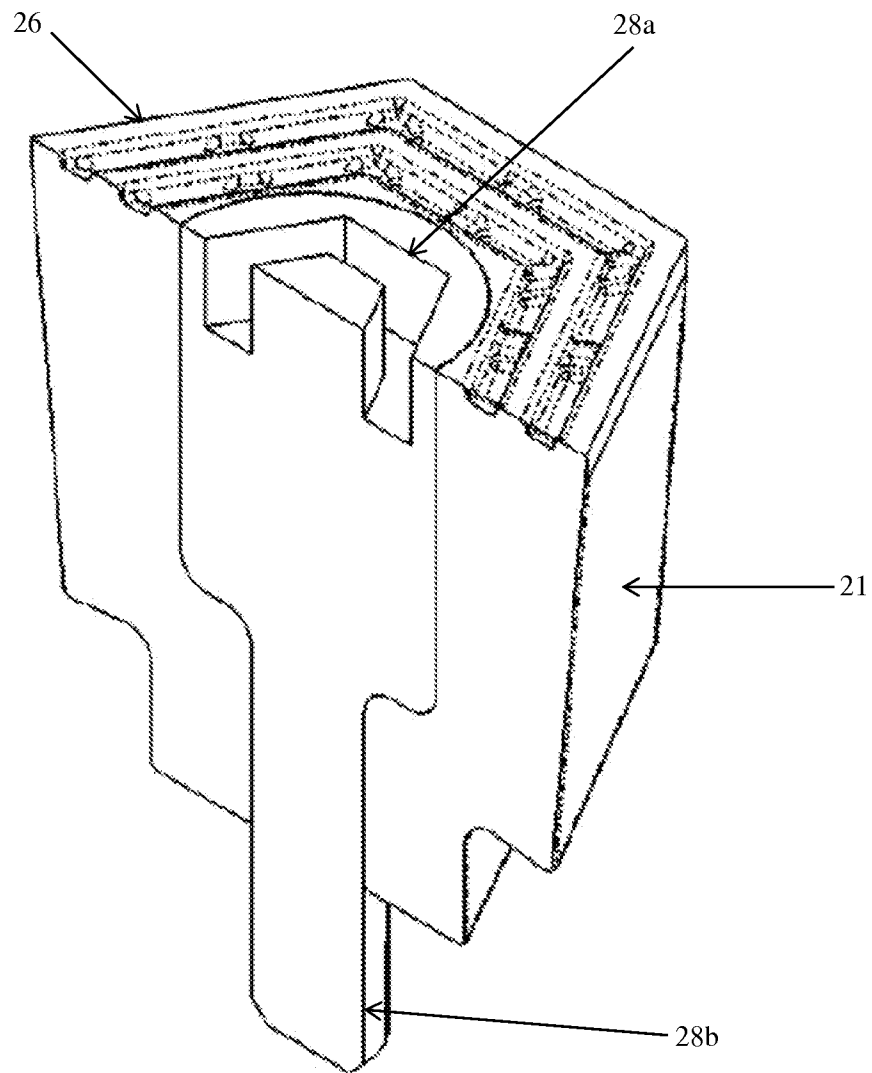
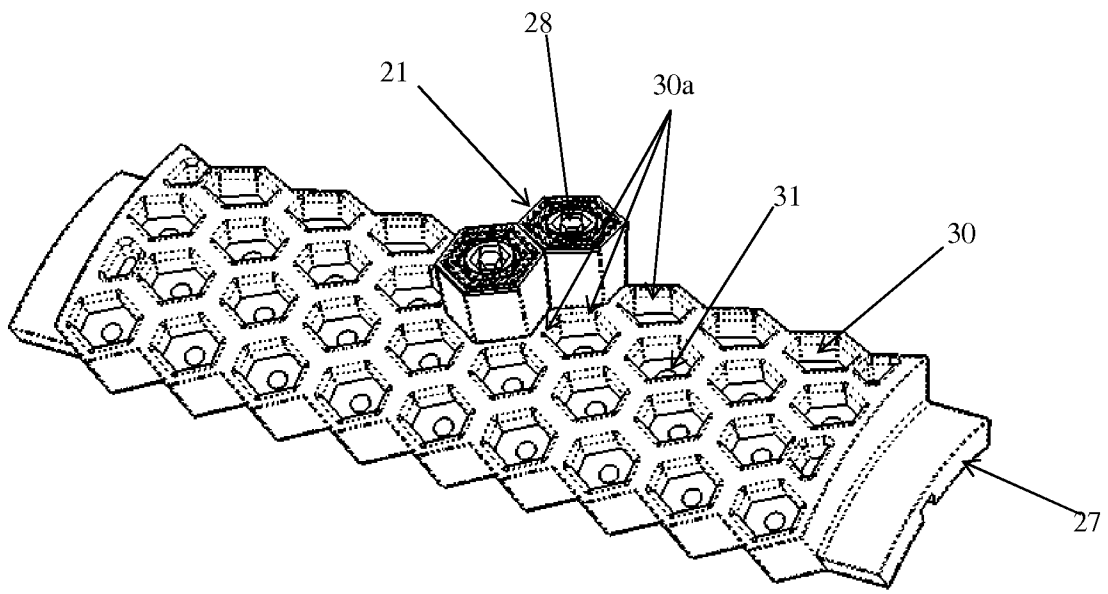
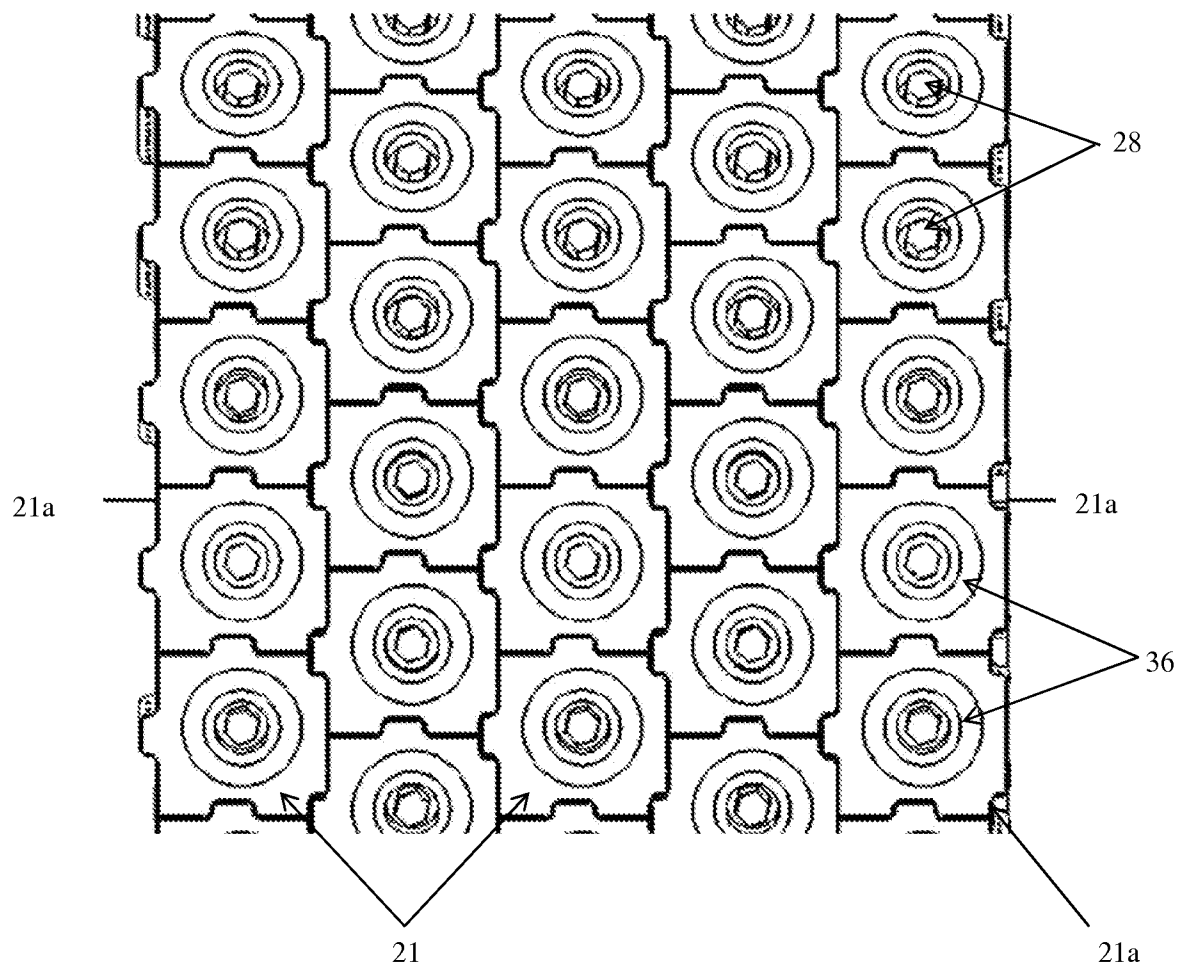


FIGURE 8

**FIGURE 9**

**FIGURE 10**

**FIGURE 11**

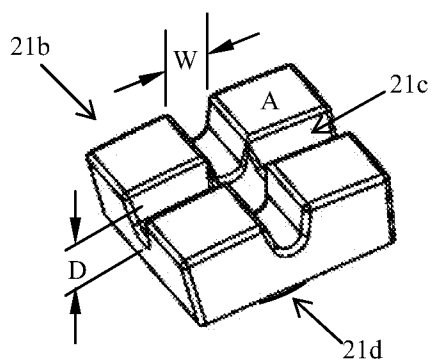


FIGURE 12A

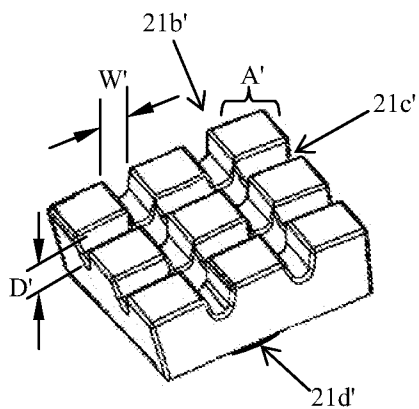


FIGURE 12B

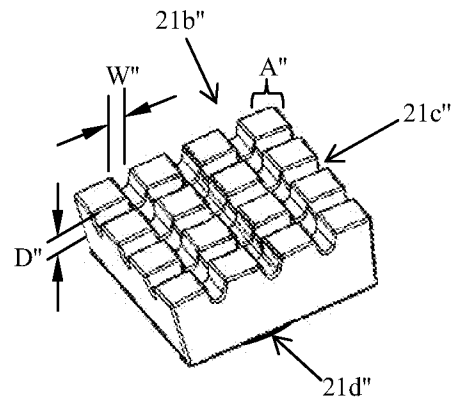


FIGURE 12C

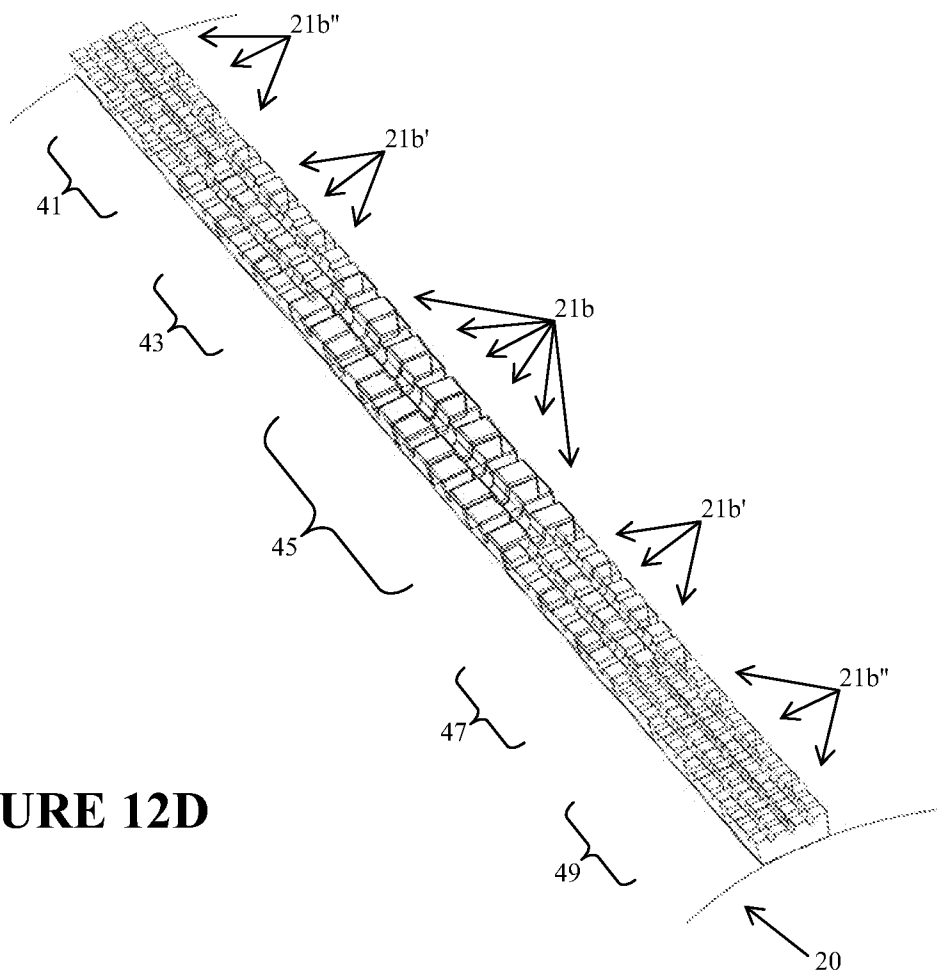


FIGURE 12D

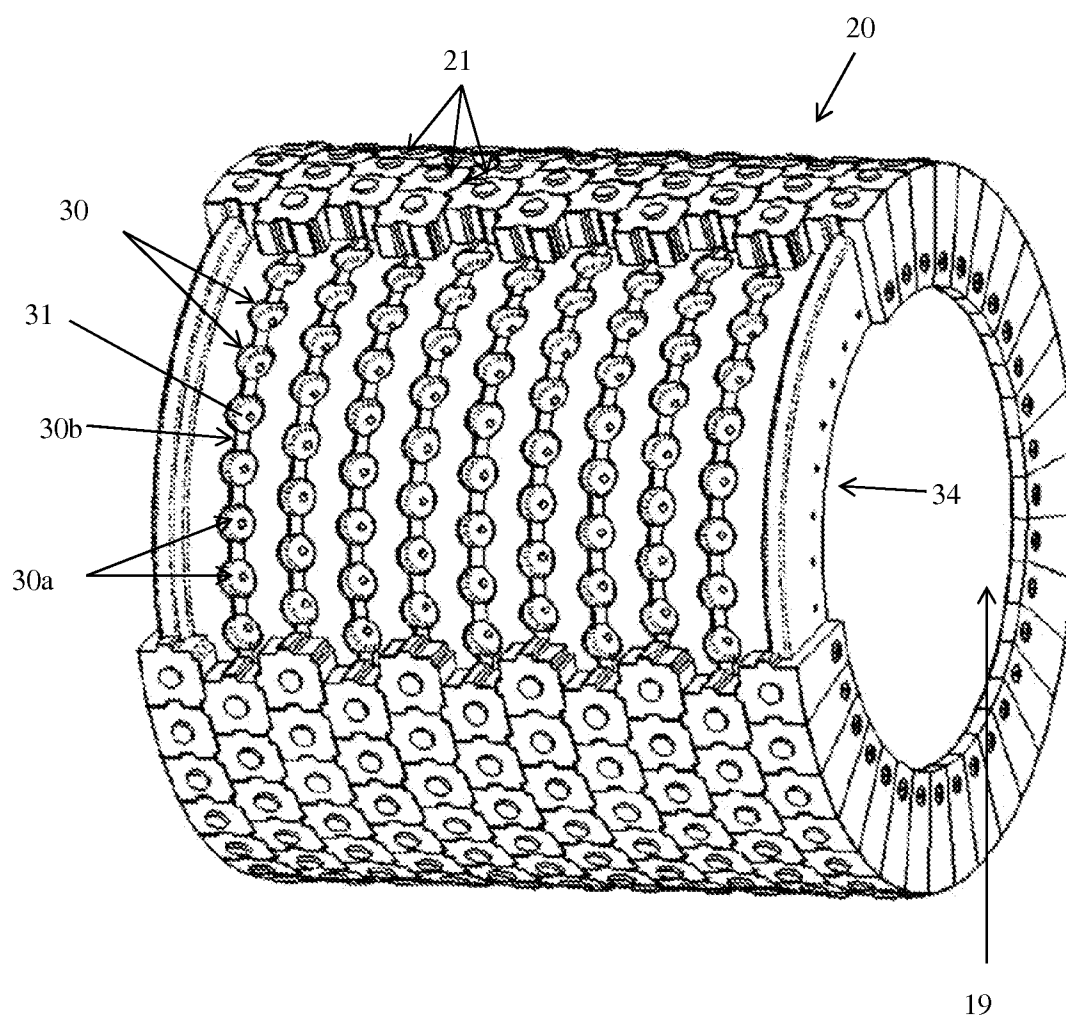
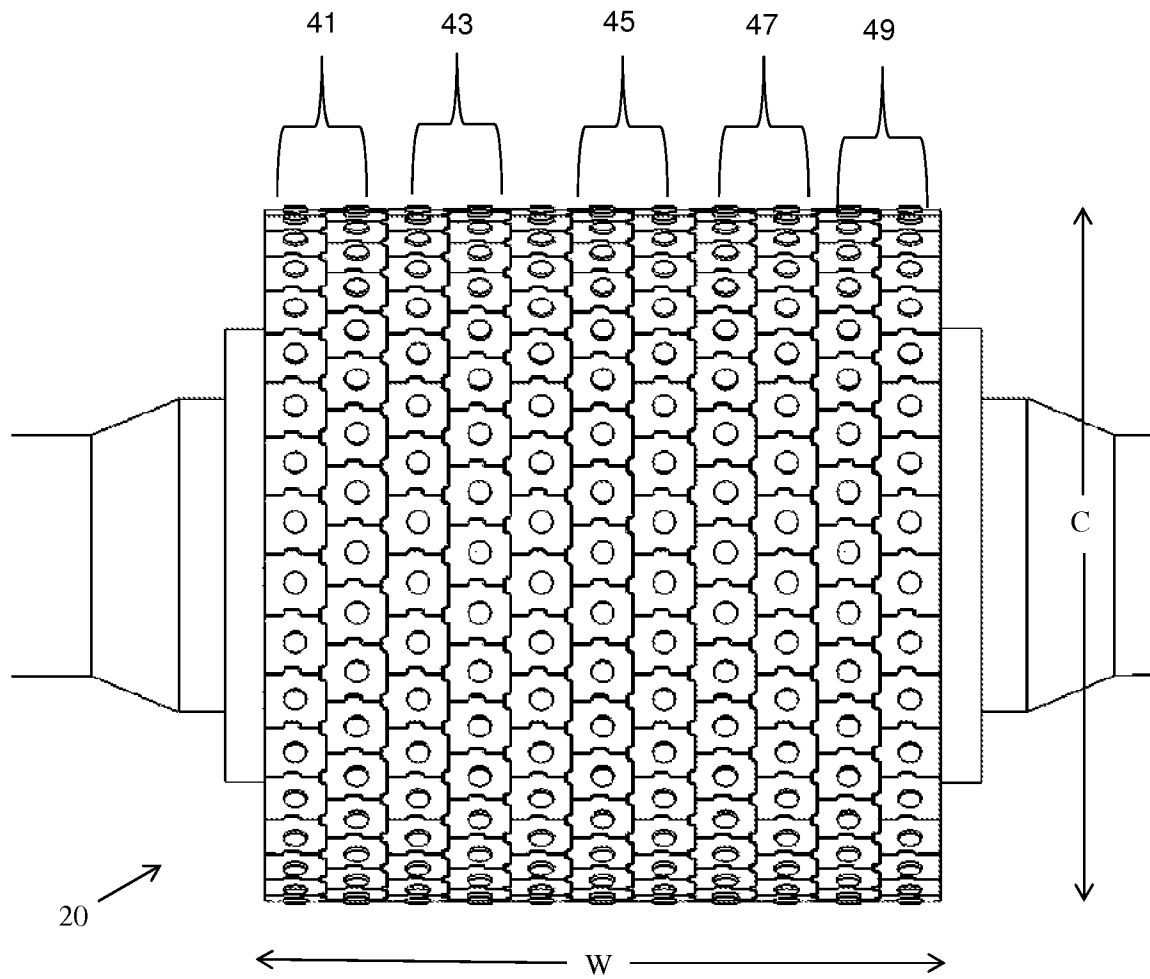
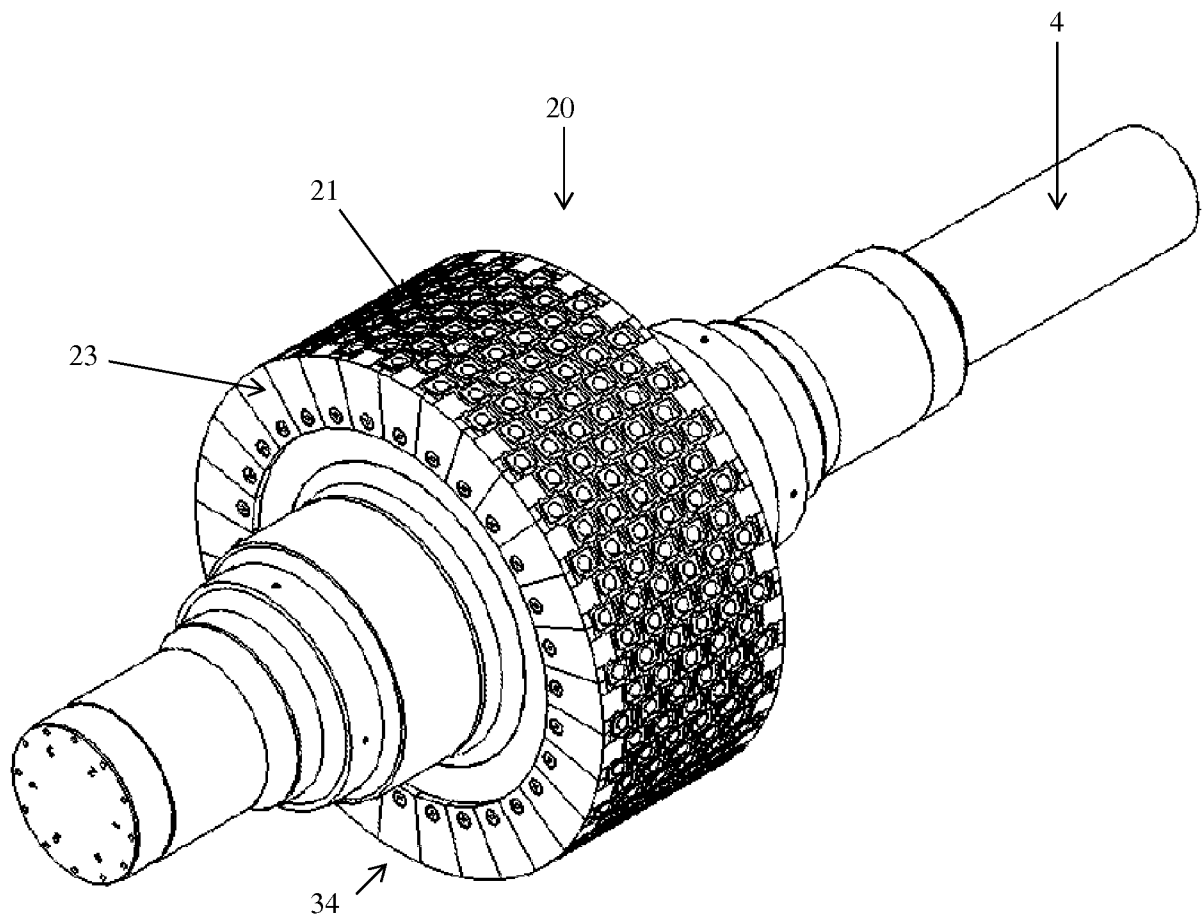
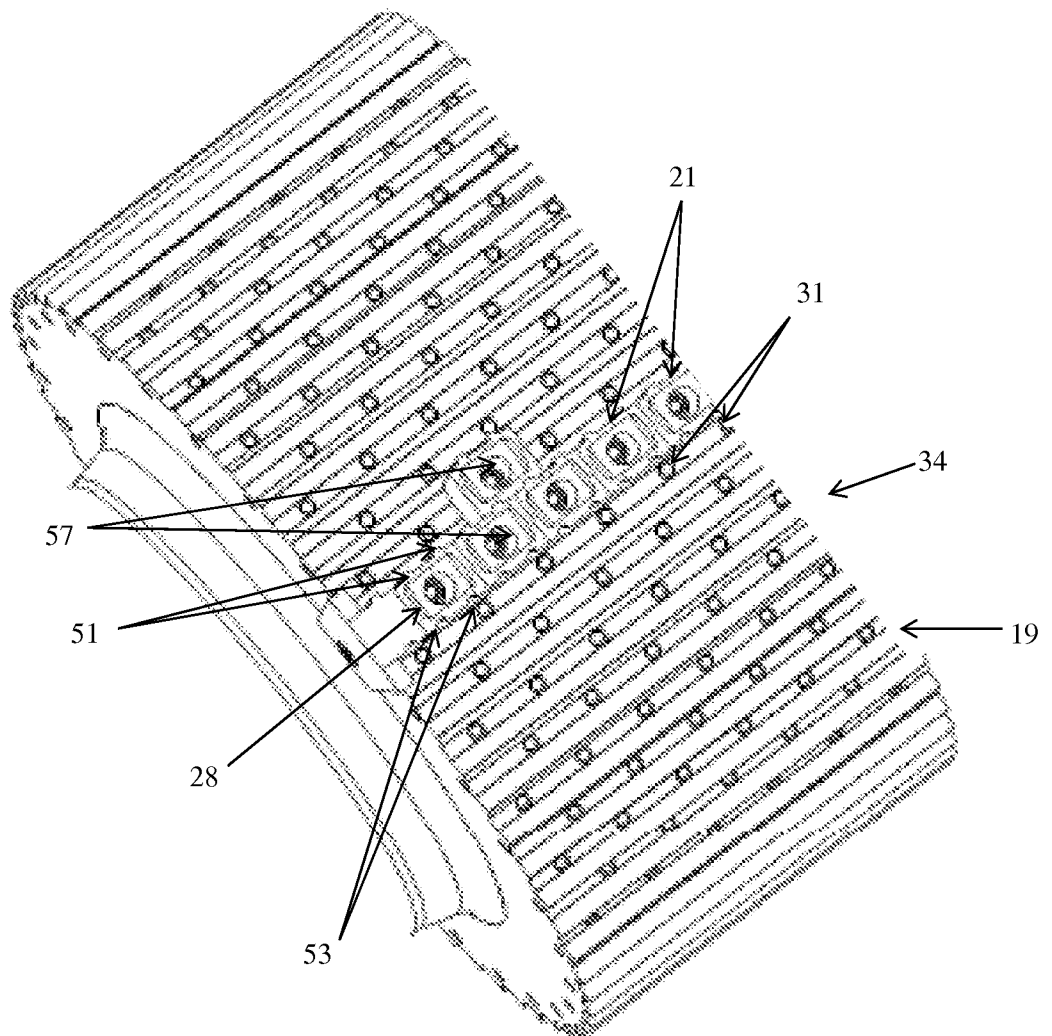


FIGURE 13

**FIGURE 14**

**FIGURE 15**

**FIGURE 16**

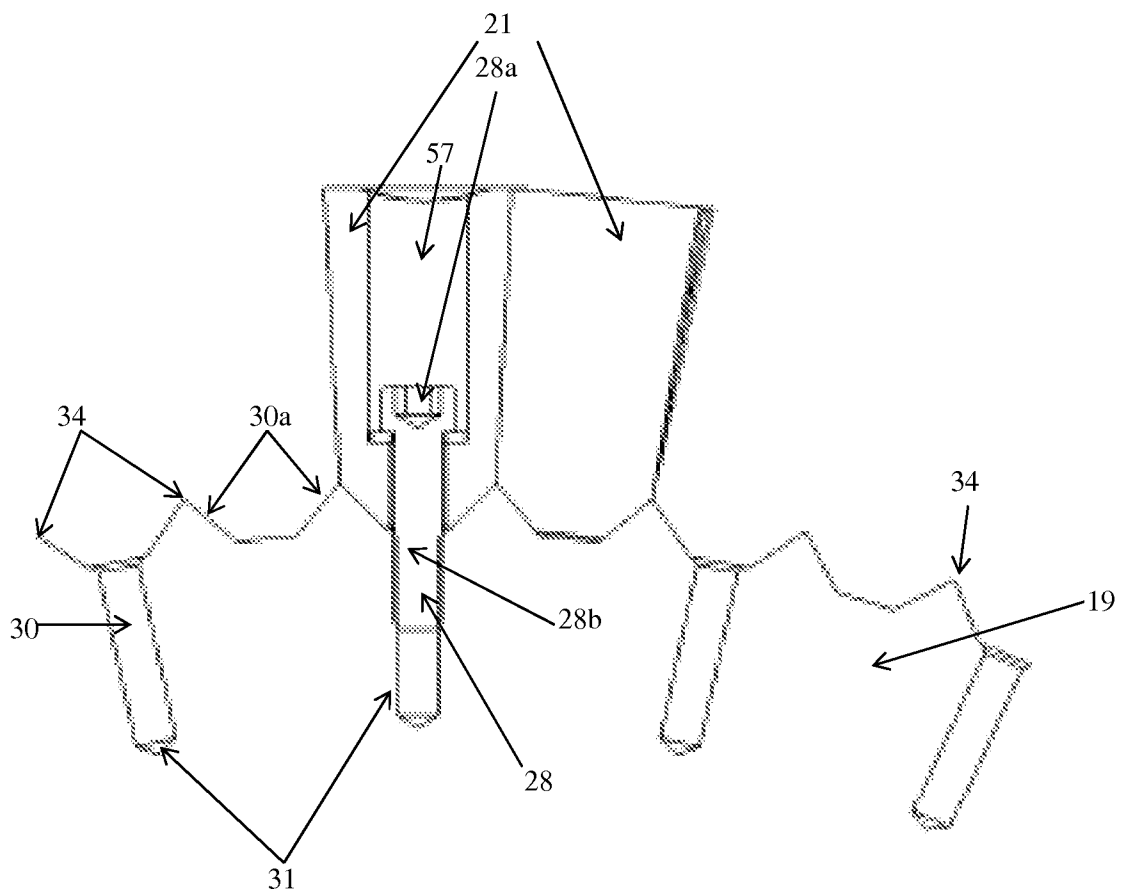
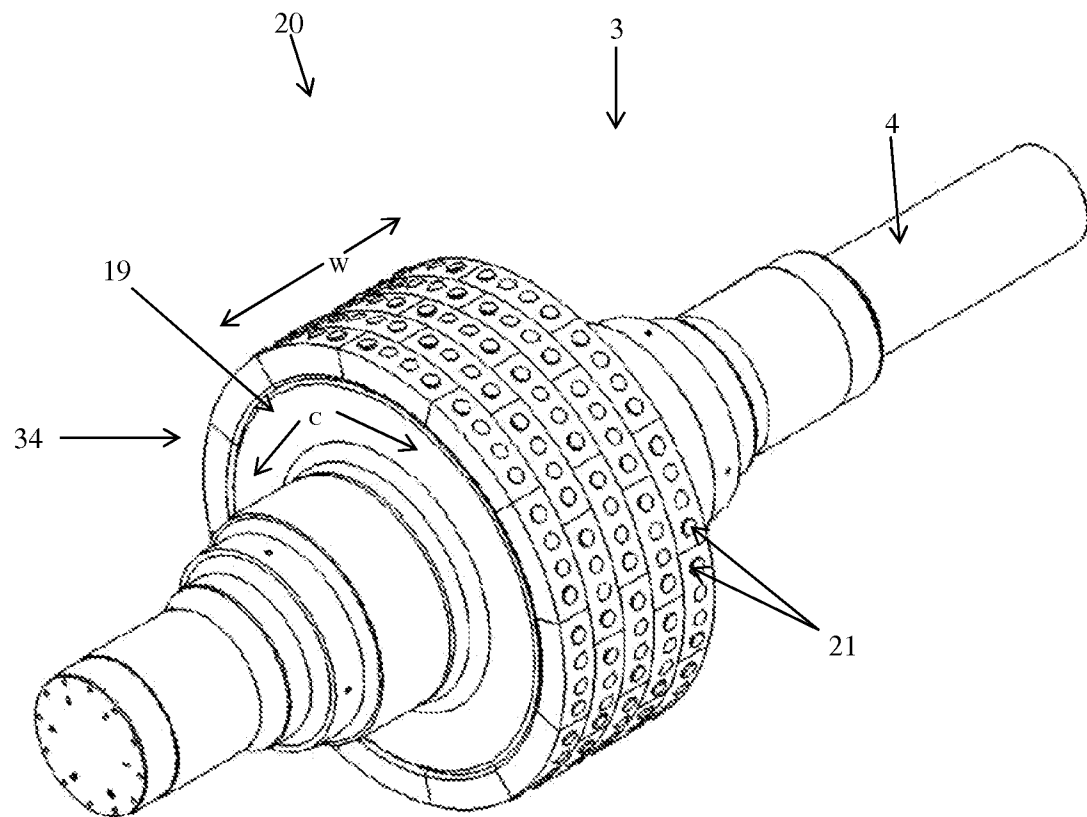
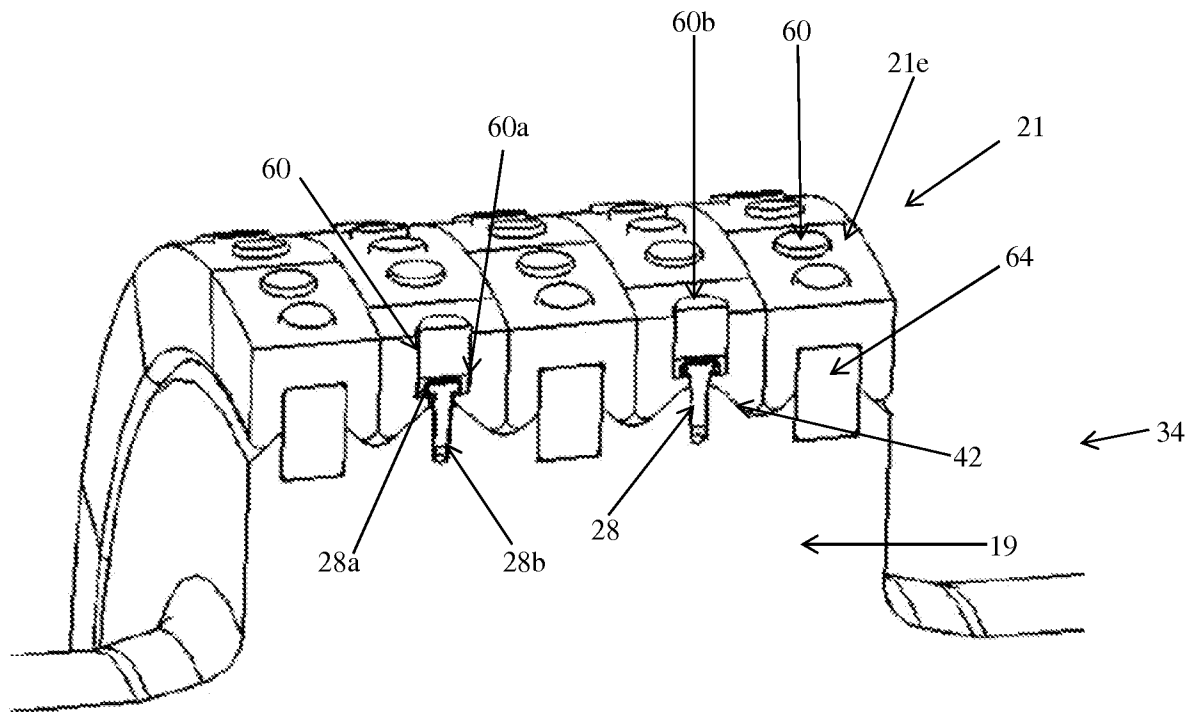


FIGURE 17

**FIGURE 18**

**FIGURE 19**

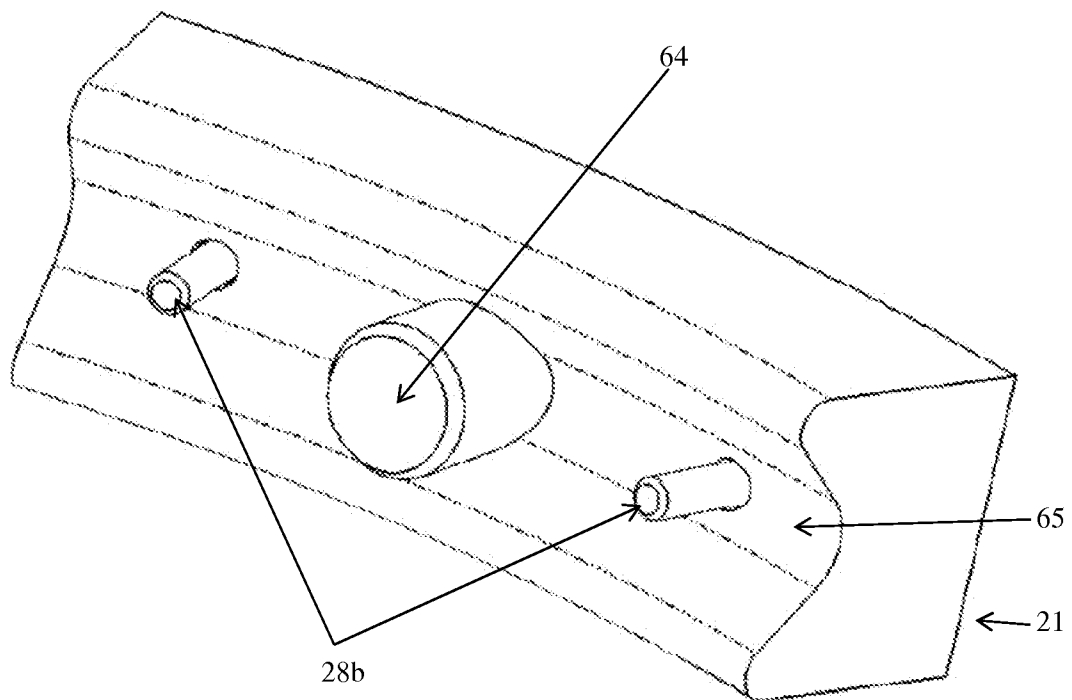
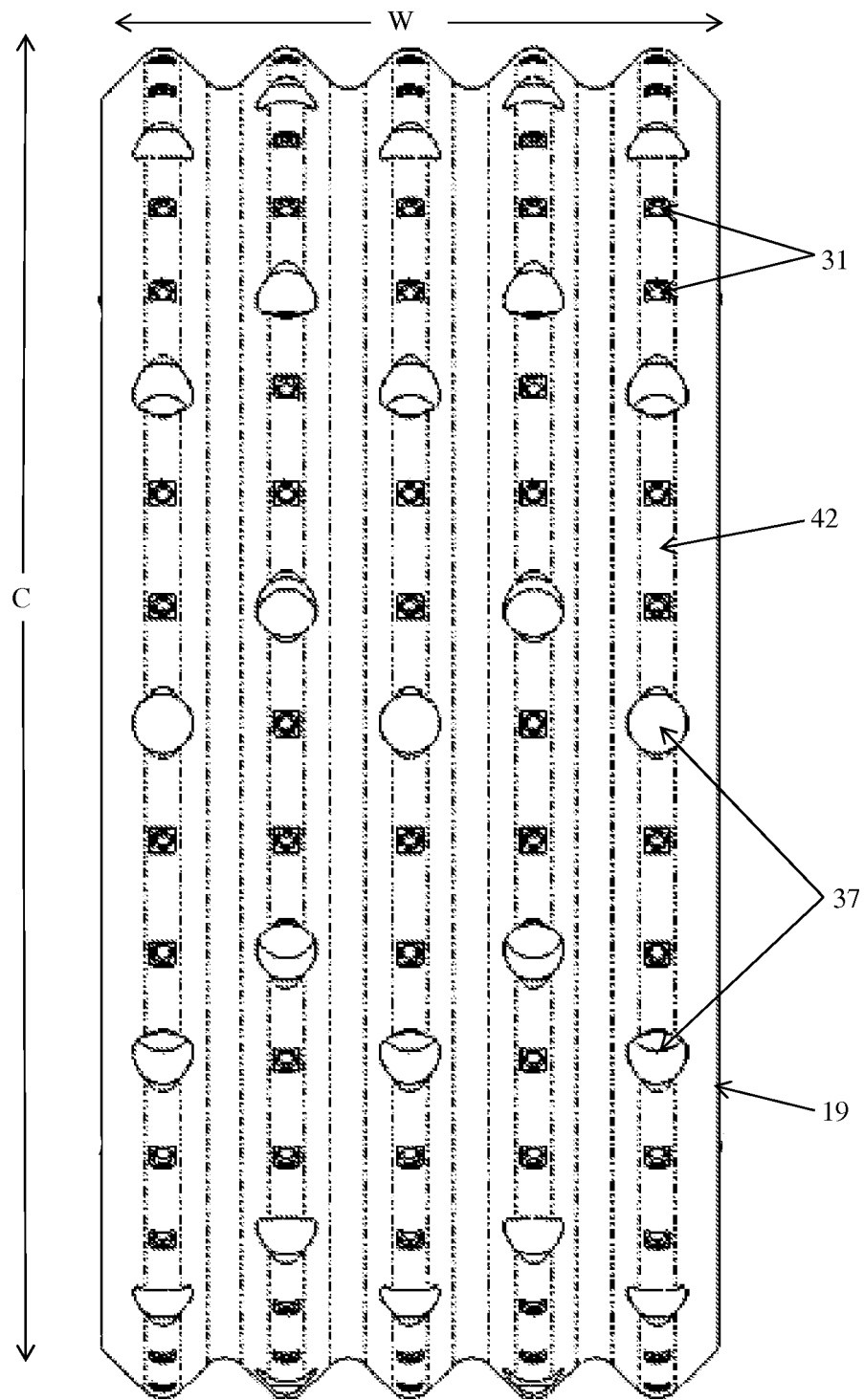
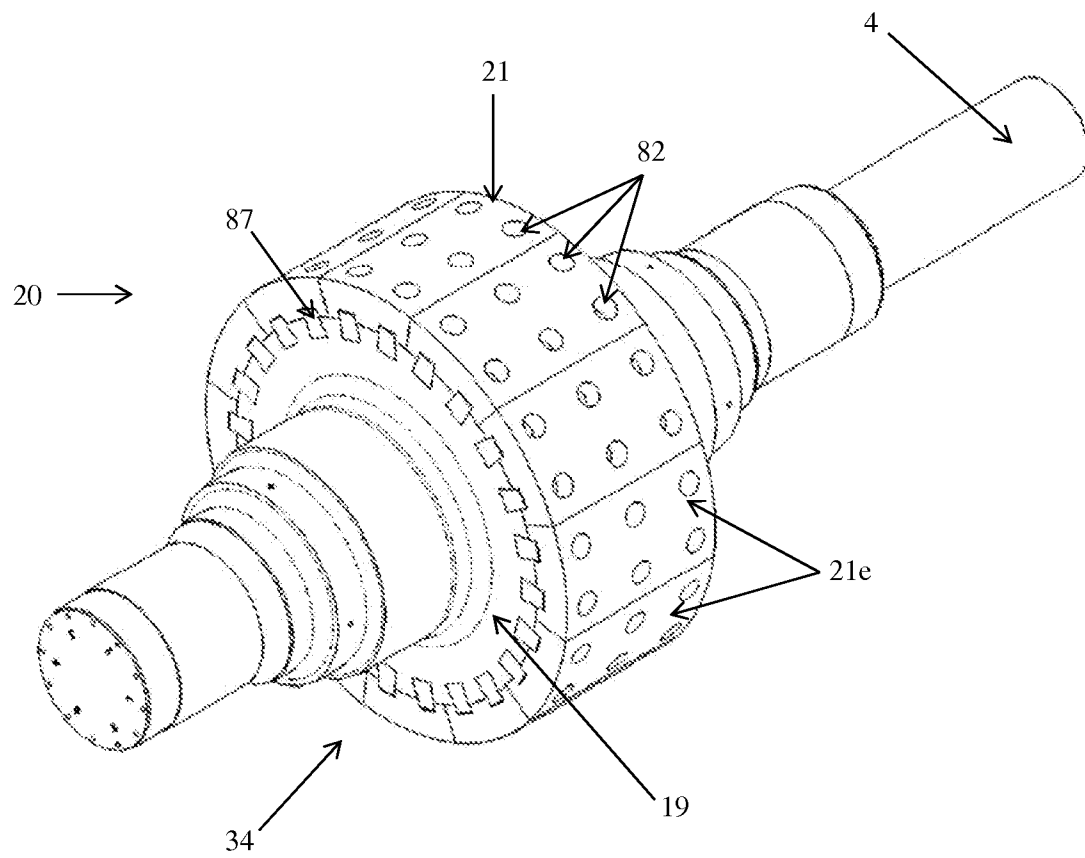


FIGURE 20

**FIGURE 21**

**FIGURE 22**

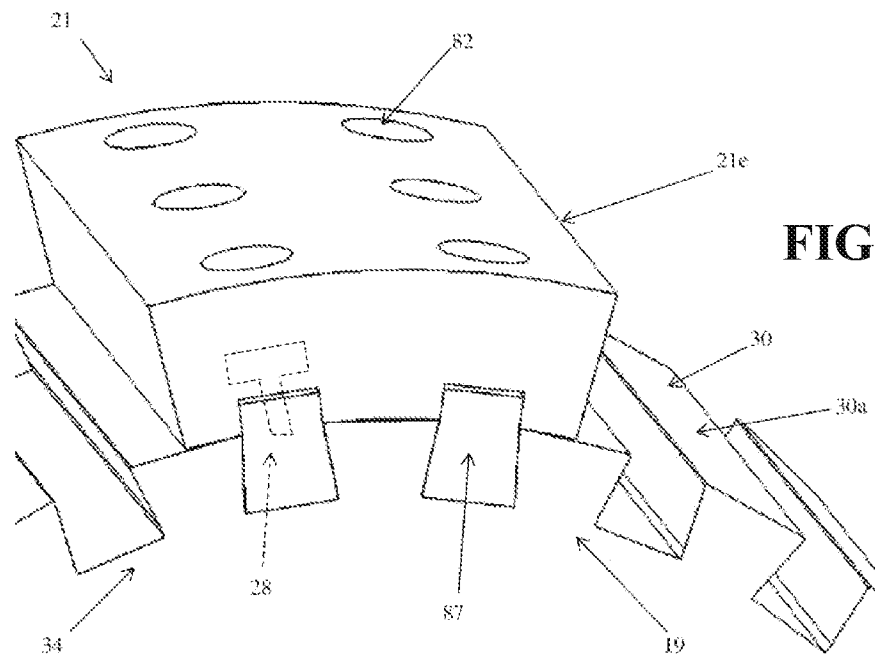


FIGURE 23

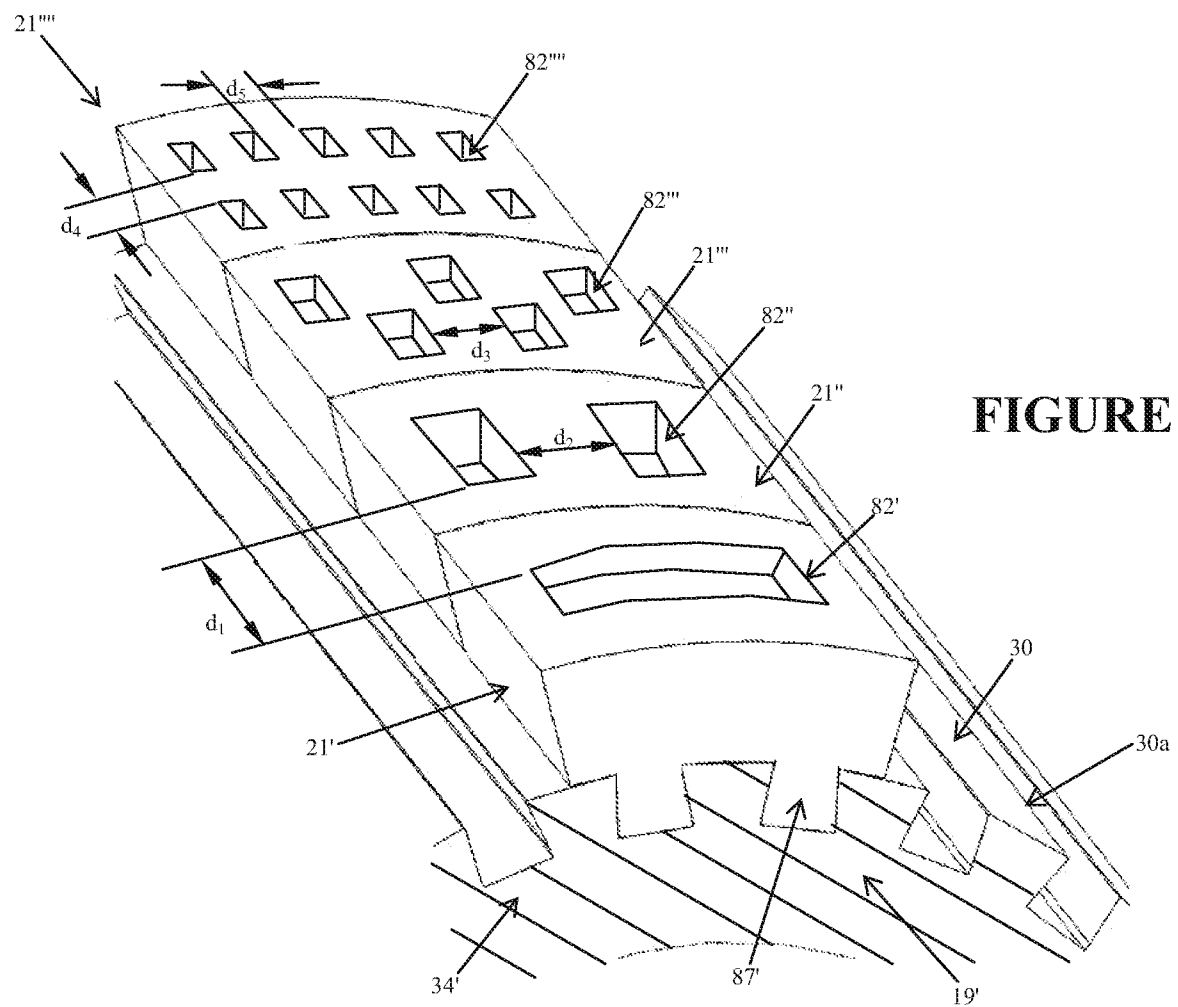
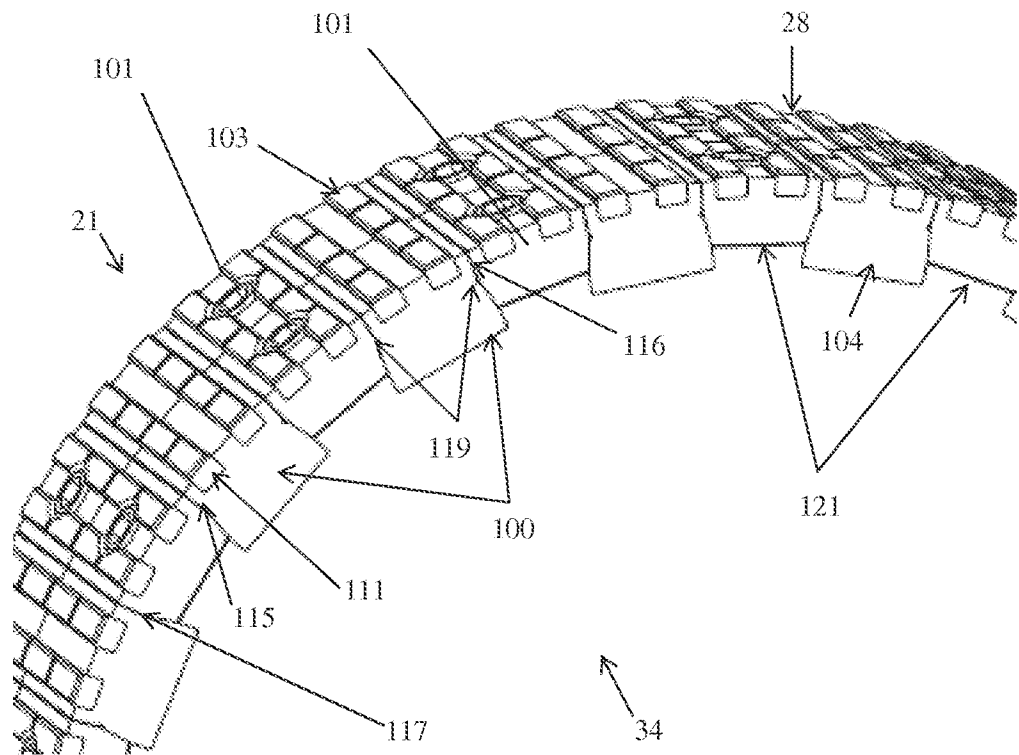


FIGURE 24

**FIGURE 25**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US13/74010

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - B02C 04/30 (2014.01)

USPC - 241/293, 294, 300

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)

IPC(8)- B02C 04/30 (2014.01)

USPC - 241/293, 294, 300

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)

MicroPatent (US Granted, US Applications, EP-A, EP-B, WO, JP, DE-G, DE-A, DE-T, DE-U, GB-A, FR-A); Google; Google Scholar; ProQuest; Comminut*, Crush*, Pulveriz*, Grind*, Mill*, Compact*, Wearable ADJ3 surface, Crushing ADJ3 surface, Crushing ADJ3 body

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2012/0048980 A1 (SCHANTZ, D.R.) 01 March 2012; figures 1- 3, 6-8, 10-10b, paragraphs [0046-0055], [0076-0079], [0083-0087], [0092-0093]	1-5, 10, 14-23 --- 6-9, 11-13
Y	US 4,915,311 A (GRACHTRUP, H. et al.) 10 April 1990; figure 4; column 2, lines 5-25, column 3, lines 20-50	6-8, 11
Y	WO 2012/031324 A1 (STEINER, K.P et al.) 15 March 2012; figures 1-9; abstract; column 3, lines 5-20, column 11, lines 10-20	9
Y	US 2011/0008569 A1 (MADOK, J. H. et al.) 13 January 2011; figures 7a, 7b, and 7c; paragraphs [0010-0011], [0072-0074]	12
Y	US 5,114,082 A (BRUNDIEK, H.) 19 May 1992; figure 4a; column 3, lines 45-60, column 5, lines 10-45	13

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

1 April 2014 (01.04.2014)

Date of mailing of the international search report

24 APR 2014

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

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