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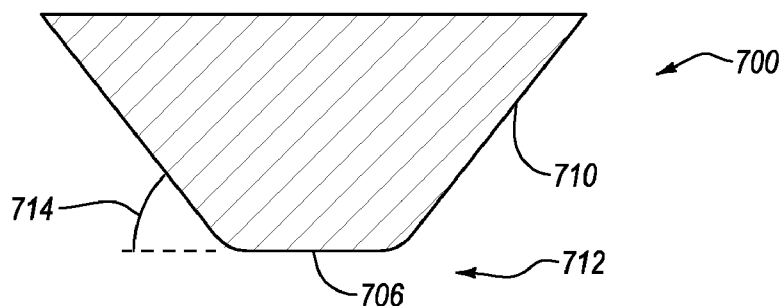


FIG. 9

(57) Abstract: An anvil for use in a high pressure press includes a nose surface and a flank surface with a transition region therebetween. The transition region includes a continuous curve that may reduce stress risers in the anvil and/or in a gasket material during application of force in the high pressure press.

DEVICES, SYSTEMS, AND METHODS FOR CONTROLLING GASKET FLOW IN A HIGH PRESSURE PRESS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to, and the benefit of, U.S. Provisional Application No. 62/316,534, filed on March 31, 2016, the entirety of which is incorporated herein by reference.

BACKGROUND OF THE DISCLOSURE

[0002] High pressure presses are used to produce stable high pressure environments for the synthesis and/or testing of materials not possible at atmospheric pressure. High pressure presses create stable environments inside a compression chamber of 800 kilopounds per square inch or greater. A high pressure press creates a high pressure environment in a steady state, allowing for sustained compression used in experiments or in the creation of ultrahard materials.

[0003] High pressure, high temperature (HPHT) presses include cubic presses, belt presses, piston-cylinder presses, and other presses. The HPHT press uses one or more anvils or dies to transmit force through the anvil to the compression chamber and compress a material placed in the chamber. The one or more anvils are separated from one another by a gasket material. The gasket material can either extrude from the compression chamber, or be placed between the anvils prior to pressurization (“preformed gaskets”). The gasket material protects the brittle anvils from direct contact and potential damage while also providing a continuous, integral seal around the periphery of the compression chamber as the pressure within the compression chamber increases.

[0004] The gasket seals the chamber during compression and decompression. Gradual decompression of the chamber and gasket after each cycling of the HPHT press ensures safe and controllable usage of the HPHT press.

SUMMARY

[0005] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

[0006] In an embodiment, an anvil for transmitting force in a high pressure press includes a body having a nose surface, at least one planar flank surface, and a transition region between the nose surface and the at least one planar flank surface. The body includes an ultrahard material. The nose surface has a nose width. The transition region is located between the nose surface and the flank surface and defines a curved surface located between the nose surface and the flank surface.

[0007] In another embodiment, a system for applying force includes a plurality of anvils. Each anvil includes a body having a nose surface, at least one planar flank surface, and a transition region between the nose surface and the at least one planar flank surface. The nose surface has a nose width. The transition region is located between the nose surface and the flank surface and defines a curved surface located between the nose surface and the flank surface.

[0008] In yet another embodiment, a method for applying pressure to a chamber includes compressing the chamber with a plurality of anvils. The anvils each have a nose surface and the nose surfaces at least partially define the chamber. The method further includes flowing a gasket material out of the chamber and over a transition region of at least one anvil. The transition region includes a curve along at least a portion of the transition region. The method further includes constraining the flow of the gasket material with the curve of the transition region.

[0009] Additional features and advantages of embodiments of the disclosure will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of such embodiments. The features and advantages of such embodiments may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features will become more fully apparent from the following description and appended claims, or may be learned by the practice of such embodiments as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] In order to describe the manner in which the above-recited and other features of the disclosure can be obtained, a more particular description will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. For better understanding, the like elements have been designated by like reference numbers throughout the various accompanying figures. While some of the drawings may be schematic or exaggerated representations of concepts, at least some of the drawings may be drawn to scale. Understanding that the drawings depict some example embodiments, the embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0011] FIG. 1 is a perspective view of an embodiment of an anvil, according to the present disclosure;

[0012] FIG. 2 is a side view of the embodiment of an anvil of FIG. 1, according to the present disclosure;

[0013] FIG. 3 is a detail side view of an embodiment of a transition region, according to the present disclosure;

[0014] FIG. 4 is a detail side view of an embodiment of a transition region with a chamfer, according to the present disclosure;

[0015] FIG. 5 is a detail side view of an embodiment of a transition region with a decreasing radius of curvature, according to the present disclosure;

[0016] FIG. 6 is a detail side view of an embodiment of a transition region with an increasing radius of curvature, according to the present disclosure;

[0017] FIG. 7 is a perspective view of another embodiment of an anvil, according to the present disclosure;

[0018] FIG. 8 is a perspective view of an embodiment of a belt press anvil, according to the present disclosure;

[0019] FIG. 9 is a side cross-sectional view of the embodiment of a belt press anvil of FIG. 8, according to the present disclosure;

[0020] FIG. 10 is a detail cross-sectional view of an embodiment of a chamber defined by a plurality of anvils, according to the present disclosure;

[0021] FIG. 11 is a detail cross-sectional view of a gasket of the chamber of FIG. 10, according to the present disclosure;

[0022] FIG. 12 is a flowchart depicting an embodiment of a method of manufacturing an anvil, according to the present disclosure; and

[0023] FIG. 13 is a flowchart depicting an embodiment of a method of using a press including one or more anvils, according to the present disclosure.

DETAILED DESCRIPTION

[0024] One or more specific embodiments of the present disclosure will be described below. These described embodiments are examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, not all features of an actual embodiment may be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous embodiment-specific decisions will be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one embodiment to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0025] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0026] This disclosure generally relates to devices, systems, and methods for applying heat and pressure in a chamber. More particularly, the present disclosure relates to the manufacturing and use of one or more anvils for use in creating a high pressure ("HP") or high pressure, high temperature ("HPHT") environment. The HP environment may sinter, shape, or otherwise form hard and/or ultrahard materials including materials known in the

art to have a grain hardness of about 1,500 HV (Vickers hardness in kg/mm²) or greater. Such ultrahard materials can include but are not limited to diamond, polycrystalline diamond (PCD), leached metal catalyst PCD, non-metal catalyst PCD, hexagonal diamond (Lonsdaleite), cubic boron nitride (cBN), polycrystalline cBN (PcBN), binderless PCD or nanopolycrystalline diamond (NPD), Q-carbon, binderless PcBN, diamond-like carbon, boron suboxide, aluminum manganese boride, metal borides, boron carbon nitride, and other materials in the boron-nitrogen-carbon-oxygen system which have shown hardness values above 1,500 HV, as well as combinations of the above materials.

[0027] A press may include one or more anvils to receive a force at a rear face and transmit the force to a compression chamber on an opposite surface of the anvil. A press may have any number of anvils. In some embodiments, the press may be a polygonal press, such as a cubic press, octohedral press, dodecahedral press, icosahedral press, or other polygonal presses. For example, a cubic press may be used to apply pressure to a cubic chamber substantially equally from six sides of the press.

[0028] Referring now to FIG. 1, force may be applied to an anvil 100, and the anvil 100 may transmit the force through a body 102 of the anvil 100 from a rear surface 104 to a nose surface 106. In some embodiments, the body 102 may include or be made of an ultrahard material. In other embodiments, the body 102 may include or be made of iron or iron alloy, such as tool steel.

[0029] The force may be applied to the rear surface 104 and/or body 102 of the anvil 100 via a hydraulic cylinder, pneumatic cylinder, magnetic ram, mechanically geared ram, or other mechanism for applying a linear force. The rear surface 104 and/or body 102 may be configured to receive the force. The anvil 100 may taper to the nose surface 106 and thereby concentrate the force applied to the body 102 to increase pressure transmitted to a chamber defined by the nose surfaces 106 of the anvils.

[0030] Some embodiments of an anvil 100 may have a flank surface 110 adjacent the nose surface 106, with a transition region 112 between and connecting the flank surface 110 and the nose surface 106. Neighboring anvils 100 in a press may approximately meet at the flank surfaces 110 of each neighboring anvil 100. In some embodiments, each anvil may have a plurality of flank surfaces 110 positioned at equal angular intervals about the longitudinal axis 108. For example, an anvil 100 may have four flank surfaces 110 oriented

at 90° intervals about the longitudinal axis 108. In another example, an anvil may have three flank surfaces oriented at 120° intervals about a longitudinal axis.

[0031] Gasket material may flow out of the compression chamber and between the flank surfaces of the neighboring anvils to seal the compression chamber and protect the anvils from directly contacting one another. A transition region 112 defining a curve may allow the gasket material to flow more predictably and controllably during compression (e.g., as compared to a non-curved, or angular transition region), allowing the press to achieve higher pressures with increased reliability and safety.

[0032] FIG. 1 illustrates an embodiment of an anvil 100 having a curved transition region 112. While the anvil 100 is shown having a four-sided nose surface 106 configured for use in a cubic press, it should be understood that one or more embodiments of an anvil 100 with a curved transition region according to the present disclosure may be configured for use in presses having other geometries. The anvil may have a body 102 with a nose surface 106, a rear surface 104, and a longitudinal axis 108 from the rear surface 104 through the nose surface 106.

[0033] The anvil 100 may include at least one flank surface 110 longitudinally between the nose surface 106 and the rear surface 104 and oriented at an angle to the nose surface 106. A transition region 112 may be between the flank surface 110 and the nose surface 106.

[0034] The transition region 112 may be a surface defining a curve connecting the nose surface 106 to the flank surface 110. In some embodiments, the transition region 112 may define a continuous curve such that the surface of the anvil 100 is continuous from nose surface 106 through the transition region 112 to the flank surface 110 without a corner or other discontinuity in the surface. In other embodiments, the transition region 112 may include both a curve and a corner. For example, the transition region 112 may be continuous from the nose surface 106, and the transition region 112 may terminate at a discontinuous corner adjacent the flank surface 110. In other examples, the transition region 112 may begin at a discontinuous corner adjacent the nose surface 106 and have a curve that is continuous through the flank surface 110. In yet other examples, the transition region 112 may include two continuous curves, a first curve continuous with and extending from the nose surface 106 and a second curve continuous with and extending from the flank

surface 110, which meet at a discontinuous corner at a point between therebetween. A transition region 112 including a curve may reduce stress risers and/or stress concentrations in the anvil 100 and/or a gasket material during application of force in an HP press.

[0035] As shown in FIG. 2, in some embodiments, the nose surface 106 of the anvil 100 may be substantially planar. For example, the nose surface 106 of the anvil 100 may be normal to the longitudinal axis 108. In other embodiments, part of the nose surface 106 may be curved in one or more directions relative to the body 102 of the anvil 100. For example, the nose surface 106 may be at least partially concave relative to the body 102 of the anvil 100. In other examples, the nose surface 106 may be at least partially convex relative to the body 102 of the anvil 100.

[0036] The flank surface 110 may extend rearward from the nose surface 106 and outward away from the longitudinal axis 108 of the anvil 100. In some embodiments, the flank surface 110 of the anvil 100 may be substantially planar. In other embodiments, part of the flank surface 110 may be curved in one or more directions relative to the body 102 of the anvil 100. For example, the nose surface 106 may be at least partially concave relative to the body 102 of the anvil 100. In other examples, the nose surface 106 may be at least partially convex relative to the body 102 of the anvil 100.

[0037] At least a portion of the transition region 112 may define a curve having a radius of curvature. In some embodiments, a radius of curvature of the transition region 112 may be a constant radius of curvature. In other embodiments, a radius of curvature of the transition region 112 may be a variable radius of curvature. For example, a curve of the transition region 112 may be at least partially described by an exponential curve, power curve, logarithmic curve, polynomial curve, spline curve, other curves, or combinations thereof.

[0038] In some embodiments, a radius of curvature of the transition region 112 may be relative to a nose width 113. The radius of curvature of the transition region 112 and the nose width 113 may have a ratio in a range having upper and lower values including any of 1:1, 1:2, 1:4, 1:6, 1:8, 1:10, 1:15, 1:20, 1:30, 1:40, 1:50, 1:75, 1:100, or any values therebetween. In some examples, the ratio may be in a range of 1:1 to 1:100. In other examples, the ratio may be in a range of 1:2 to 1:75. In yet other examples, the ratio may be in a range of 1:4 to 1:50. In at least one example, the ratio may be no greater than 1:10.

[0039] In some embodiments, at least a portion of the flank surface 110 may define a transition angle 114 relative to the nose surface 106 of the anvil 100. In other embodiments, such embodiments with a non-planar nose surface 106, the transition angle 114 may be the angle formed by the flank surface 110 relative to a plane normal to the longitudinal axis 108. For example, the transition angle 114 may be in a range having upper and lower values including any of 40°, 41°, 42°, 43°, 44°, 45°, 46°, 47°, 48°, 49°, 50°, or any value therebetween. In some examples, the transition angle 114 may be in a range between 40° and 50°. In other examples, the transition angle 114 may be in a range between 41° and 49°. In yet other examples, the transition angle 114 may be in a range between 42° and 48°. In at least one example, the transition angle 114 may be about 45°.

[0040] FIG. 3 illustrates a side cross-sectional detail of an embodiment of a transition region 212. As described in relation to FIG. 1, the transition region 212 may be located longitudinally between a nose surface 206 and a flank surface 210. The transition region 212 may define at least one curve that is continuous. For example, FIG. 3 depicts a transition region 212 including a curve with a constant radius of curvature 216. The transition region 212 may be the entire region between the nose surface 206 and the flank surface 210. The transition region 212 may, with the nose surface 206 and the flank surface 210, form a continuous surface with a constant radius of curvature 216 through the entire transition region 212. In other embodiments, the transition region 212 may be the entire region between the nose surface 206 and the flank surface 210 and a continuous curve may encompass a portion of the transition region 212 less than the entire transition region 212.

[0041] FIG. 4 illustrates another embodiment of a transition region 312 between a nose surface 306 and a flank surface 310. In some embodiments, the transition region 312 may include a portion of the transition region 312 that is a curve and a portion of the transition region 312 that is a planar chamfer 317. The planar chamfer 317 may be oriented at a different angle relative to the nose surface 306 from the flank surface 310. For example, the transition region 312 may have a constant radius of curvature 316 through at least a portion of the transition region 312 that provides a continuous surface with the planar chamfer 317. In other examples, the transition region 312 may have a discontinuous corner between at least a portion of the transition region 312 with a constant radius of curvature 316 and the planar chamfer 317.

[0042] An embodiment of a transition region 412 having a plurality of radii of curvature is shown in FIG. 5. For example, the transition region 412 may include one or more curves such that the transition region 412 has a first radius of curvature 416-1 greater than a second radius of curvature 416-2. The first radius of curvature 416-1 may be the radius of curvature of the transition region 412 at or nearer the connection with the nose surface 406 and the second radius of curvature 416-2 may be the radius of curvature of the transition region 412 at or nearer the connection with the flank surface 410. In some embodiments, the first radius of curvature 416-1 and second radius of curvature 416-2 may define a decreasing radius of curvature in the transition region 412. For example, the first radius of curvature 416-1 and second radius of curvature 416-2 may have a total transition ratio. A total transition ratio may be the ratio of the first radius of curvature 416-1 to the second radius of curvature. For example, a transition region 412 with a first curvature of radius 416-1 twice as large as a second curvature of radius 416-2 has a total transition ratio of 2.0:1. In some embodiments, the total transition ratio may be in a range having upper and lower values including any of 1.5:1, 2.0:1, 4.0:1, 6.0:1, 8.0:1, 10.0:1, 20.0:1, 40.0:1, 60.0:1, 80.0:1, 100.0:1, or any value therebetween. In some examples, the total transition ratio may be in a range of 1.5:1 to 100.0:1. In other examples, the total transition ratio may be in a range of 2.0:1 to 80.0:1. In yet other examples, the total transition ratio may be in a range of 4.0:1 to 60.0:1. In other embodiments, the total transition ratio may be greater than 100.0:1.

[0043] In other embodiments, the transition region 412 may have an upper radius of curvature and a lower radius of curvature. For example, the transition region 412 may have a plurality of radii of curvature and the upper radius of curvature may be greatest radius of curvature and the lower radius of curvature may be the smallest radius of curvature. In some embodiments, the upper radius of curvature may be the radius of curvature of the transition region 412 at or nearer the connection with the nose surface 406 and the lower radius of curvature may be the radius of curvature of the transition region 412 at or nearer the connection with the flank surface 410. For example, the upper radius of curvature may be the first radius of curvature 416-1 and the lower radius of curvature may be the second radius of curvature 416-2. In other embodiments, the upper radius of curvature and the lower radius of curvature may be radii of curvature at other locations in the transition region

412. In some examples, the upper radius of curvature may be at or near a center point of the transition region 412. In other examples, the lower radius of curvature may be at or near a center point of the transition region 412.

[0044] In some embodiments, the upper radius of curvature and lower radius of curvature may define a decreasing radius of curvature in the transition region 412. For example, the upper radius of curvature and lower radius of curvature may have a displacement transition ratio. A displacement transition ratio may be the ratio of the upper radius of curvature to the lower radius of curvature. For example, a transition region 412 with an upper radius of curvature, irrespective of the location of the upper radius of curvature within the transition region, twice as large as a lower radius of curvature has a displacement transition ratio of 2.0:1. In some embodiments, the displacement transition ratio may be in a range having upper and lower values including any of 1.5:1, 2.0:1, 4.0:1, 6.0:1, 8.0:1, 10.0:1, 20.0:1, 40.0:1, 60.0:1, 80.0:1, 100.0:1, or any value therebetween. In some examples, the displacement transition ratio may be in a range of 1.5:1 to 100.0:1. In other examples, the displacement transition ratio may be in a range of 2.0:1 to 80.0:1. In yet other examples, the displacement transition ratio may be in a range of 4.0:1 to 60.0:1. In other embodiments, the displacement transition ratio may be greater than 100.0:1.

[0045] Another embodiment of a transition region 512 having a plurality of radii of curvature is shown in FIG. 6. For example, the transition region 512 may include one or more curves such that the transition region 512 has a first radius of curvature 516-1 less than a second radius of curvature 516-2. The first radius of curvature 516-1 may be the radius of curvature of the transition region 512 at or nearer the connection with the nose surface 506 and the second radius of curvature 516-2 may be the radius of curvature of the transition region 512 at or nearer the connection with the flank surface 510. In some embodiments, the first radius of curvature 516-1 and second radius of curvature 516-2 may define an increasing radius of curvature in the transition region 512. For example, the first radius of curvature 516-1 and second radius of curvature 516-2 may have a total transition ratio. A total transition ratio may be the ratio of the first radius of curvature 516-1 to the second radius of curvature. For example, a transition region 512 with a first curvature of radius 516-1 half as large as a second curvature of radius 516-2 has a total transition ratio of 1:2.0. In some embodiments, the total transition ratio may be in a range having upper

and lower values including any of 1:1.5, 1:2.0, 1:4.0, 1:6.0, 1:8.0, 1:10.0, 1:20.0, 1:40.0, 1:60.0, 1:80.0, 1:100.0, or any value therebetween. In some examples, the total transition ratio may be in a range of 1:1.5 to 1:100.0. In other examples, the total transition ratio may be in a range of 1:2.0 to 1:80.0. In yet other examples, the total transition ratio may be in a range of 1:4.0 to 1:60.0. In other embodiments, the total transition ratio may be less than 1:100.0.

[0046] In other embodiments, the transition region 512 may have an upper radius of curvature and a lower radius of curvature. For example, the transition region 512 may have a plurality of radii of curvature and the upper radius of curvature may be the greatest radius of curvature and the lower radius of curvature may be the smallest radius of curvature. In some embodiments, the lower radius of curvature may be the radius of curvature of the transition region 512 at or nearer the connection with the nose surface 506 and the upper radius of curvature may be the radius of curvature of the transition region 512 at or nearer the connection with the flank surface 510. For example, the lower radius of curvature may be the first radius of curvature 516-1 and the upper radius of curvature may be the second radius of curvature 516-2. In other embodiments, the upper radius of curvature and the lower radius of curvature may be radii of curvature at other locations in the transition region 512. In some examples, the upper radius of curvature may be at or near a center point of the transition region 512. In other examples, the lower radius of curvature may be at or near a center point of the transition region 512.

[0047] Referring now to FIG. 7, an embodiment of an anvil 600 according to the present disclosure may have a first flank surface 610-1 and a second flank surface 610-2 with a flank transition surface 618 therebetween. The flank transition surface 618 may be located at the edge at which the first flank surface 610-1 and second flank surface 610-2 meet. In some embodiments, a portion of the flank transition surface 618 (e.g., an end of the flank transition surface 618) may be adjacent to and/or abutting a nose surface 606.

[0048] The flank transition surface 618 may have cross-sectional profile similar to a transition region described herein. In some embodiments, the flank transition surface 618 may have a discontinuity in the surface, such as a corner or other discontinuous angle. In other embodiments, the flank transition surface 618 may be a substantially continuous surface with one or more curves between the first flank surface 610-1 and the second flank

surface 610-2. For example, a flank transition surface 618 may have one or more curves having a constant radius of curvature, similar to the transition region 212 described in relation to FIG. 3. In other examples, the flank transition surface 618 may have one or more curves having a plurality of radii of curvature such as curve having a decreasing radius of curvature, similar to the transition region 412 as described in relation to FIG. 5, and/or an increasing radius of curvature, similar to the transition region 512 as described in relation to FIG. 6. In yet other examples, a portion of the flank transition surface 618 may have a decreasing radius and another portion of the flank transition surface 618 may have an increasing radius. In at least one embodiment, a flank transition surface 618 may include both one or more curves and at least one discontinuous corner.

[0049] In some embodiments, an embodiment of an anvil according to the present disclosure may be configured for transmitting force in a belt press. FIG. 8 illustrates an embodiment of an anvil 700 configured to transmit force to an end of a cylindrical high pressure chamber. The anvil 700 may have a generally conical shape with a rear surface 704 opposite a nose surface 706. A flank surface 710 may be adjacent the nose surface 706 and extend circumferentially about a longitudinal axis 708 of the anvil 700. At least a portion of the nose surface 706 may be perpendicular to the longitudinal axis 708. In other embodiments, the nose surface 706 may be convex and/or concave.

[0050] The flank surface 710 may be generally conical and oriented at an angle to the nose surface 706. FIG. 9 depicts a side cross-sectional view of the embodiment of an anvil 700. At least a portion of the flank surface 710 may be planar in cross-section and a transition region 712 may connect the planar portion of the flank surface 710 to the nose surface 706.

[0051] In some embodiments, the transition region 712 may define a transition angle 714 of the flank surface 710 relative to the nose surface 706. In other embodiments, such embodiments with a non-planar nose surface 706, the transition angle 714 may be the angle formed by the flank surface 710 relative to a plane 90° from the longitudinal axis 708. For example, the transition angle 714 may be in a range having upper and lower values including any of 40°, 41°, 42°, 43°, 44°, 45°, 46°, 47°, 48°, 49°, 50°, or any value therebetween. In some examples, the transition angle 714 may be in a range between 40° and 50°. In other examples, the transition angle 714 may be in a range between 41° and

49°. In yet other examples, the transition angle 714 may be in a range between 42° and 48°. In at least one example, the transition angle 714 may be about 45°.

[0052] FIG. 9 depicts the transition region 712 including a curve with a constant radius of curvature. Similar to the embodiments described in relation to FIG. 1 through FIG. 8, the transition region 712 may be the entire region between the nose surface 706 and the flank surface 710. The transition region 712 may, with the nose surface 706 and the flank surface 710, form a continuous surface with a constant radius of curvature through the entire transition region 712. In other embodiments, the transition region 712 may be the entire region between the nose surface 706 and the flank surface 710 and a continuous curve may encompass a portion of the transition region 712 less than the entire transition region 712.

[0053] A system having one or more anvils according to the present disclosure may define a chamber in which high pressure and/or high temperatures may be generated. In some embodiments, the system may include six anvils arranged at orthogonal angles to one another and defining a cubic press. FIG. 10 is a side cross-sectional view of a chamber 820 in a cubic press. Four of the anvils 800 are visible in the cross-section: a first anvil 800-1, a second anvil 800-2, a third anvil 800-3, and a fourth anvil 800-4. A fifth anvil and sixth anvil may be positioned normal to the cross-section depicted in FIG. 10.

[0054] The anvils may define a chamber 820 in which a gasket material 822 may be compressed and/or heated. During compression of the gasket material 822 in the chamber 820 by the anvils, a portion of the gasket material 822 may extrude between neighboring flank surfaces of the anvils. For example, the gasket material 822 may extrude between the first anvil flank surface 810-1 and the second anvil flank surface 810-2. A width of the gasket material 822 between the first anvil flank surface 810-1 and the second anvil flank surface 810-2 may be in a range having upper and lower values including any of 0.25mm, 0.5mm, 1.0mm, 2.0mm, 3.0mm, 4.0mm, 6.0mm, 7.0mm, 8.0mm, or any values therebetween. For example, the width of the gasket material 822 between the first anvil flank surface 810-1 and the second anvil flank surface 810-2 may be in a range of 0.25mm to 8.0mm. In other examples, the width of the gasket material 822 between the first anvil flank surface 810-1 and the second anvil flank surface 810-2 may be in a range of 0.5mm to 6.0mm. In yet other examples, the width of the gasket material 822 between the first

anvil flank surface 810-1 and the second anvil flank surface 810-2 may be in a range of 1.0mm to 3.0mm.

[0055] Referring now to FIG. 11, a detail view of the gasket material 822 at the transition regions may be seen. In some embodiments, the gasket material 822 may be extruded between adjacent transition regions to the space between the first anvil flank surface 810-1 and the second anvil flank surface 810-2. For example, the gasket material 822 may be extruded between the first anvil transition region 812-1 and the second anvil transition region 812-2. The gasket material 822 may have a decreasing thickness as the gasket material 822 extrudes from the chamber 820 between the anvils. An initial gasket thickness 824 may taper down to a final gasket thickness 826 between the first anvil transition region 812-1 and the second anvil transition region 812-2. The final gasket thickness may be the thickness of the gasket material in the space between the first anvil flank surface 810-1 and the second anvil flank surface 810-2.

[0056] In some embodiments, the initial gasket thickness 824 and final gasket thickness 826 may have a gasket ratio in a range having upper and lower values including any of 1.2:1, 1.4:1, 1.6:1, 1.8:1, 2.0:1, 2.5:1, 3.0:1, 3.5:1, 4.0:1, 4.5:1, 5.0:1, 6.0:1, 7.0:1, 8.0:1, 9.0:1, 10.0:1, 12.0:1, 14.0:1, 16.0:1, 18.0:1, 20.0:1, 25.0:1, 30.0:1, 40.0:1, 50.0:1, 100.0:1, or any values therebetween. For example, the gasket ratio may be in a range of 1.2 to 100.0. In other examples, the gasket ratio may be in a range of 1.4 to 50.0. In yet other examples, the gasket ratio may be in a range of 1.6 to 20.0. In at least one example, the gasket ratio may be about 5.0.

[0057] In some embodiments, the gasket material 822 may include pyrophyllite, graphite or other carbon; a salt; a polymer, such as nitrile butadiene rubber, clay, other incompressible materials, or combinations thereof.

[0058] FIG. 12 illustrates a method 928 of manufacturing an anvil according to the present disclosure. The method 928 may be used to manufacture one or more embodiments of anvils as described herein. The method 928 may include casting 930 the anvil and grinding 932 the transition region of the anvil. For example, the method 928 may include casting 930 a carbide powder or other precursor powder to produce the cast form (i.e., the general shape) of an embodiment of an anvil, as described herein. In some embodiments, the cast form may have a nose surface and at least one flank surface.

[0059] In some embodiments, the powder may be a single phase powder that may be cast by sintering together the particles of the powder through recrystallization and/or interstitial growth. In other embodiments, the powder may be a multi-phase powder including an ultrahard material powder and a catalyst material to lower the recrystallization energy. In yet other embodiments, the powder may be a multi-phase powder including an ultrahard material powder and a binding phase with a lower recrystallization and/or binding energy. The binding phase may form a matrix around the particles of the ultrahard material and hold the particles of ultrahard material.

[0060] The method 928 may further include grinding 932 a portion of the cast form to produce a transition region between the nose surface and the flank surface. In some embodiments, the method 928 may include grinding 932 at least a portion of the nose surface. In other embodiments, the method 928 may include grinding 932 at least a portion of the flank surface. In some embodiments, the method 928 may also include pre-sintering the mixture of powder and/or other phases and green state machining at least a portion of the resulting form.

[0061] In some embodiments, the catalyst phase and/or binding phase may be leached from the anvil prior to grinding 932 the anvil. In other embodiments, the catalyst phase and/or binding phase may be leached from the anvil prior to casting 930 the anvil. In at least one embodiment, the catalyst phase and/or binding phase may be leached from the anvil after grinding 932 the anvil.

[0062] FIG. 13 illustrates a method 934 of using a high pressure press having one or more anvils according to the present disclosure. The method 934 may be used with one or more embodiments of anvils as described herein. The method 934 may include compressing 936 a cell comprising an assembly of one or more materials in a chamber and flowing 938 at least a portion of the one or more materials out of the chamber and past at least a portion of a transition region of the anvil to form a gasket. The method 934 may include constraining 940 the movement of the gasket material with the transition region. In some embodiments, the method 934 may further include decompressing the gasket material and/or chamber. As used herein, a “gasket material” should be understood to refer to the one or more materials used the cell and/or between the anvils. For example, the gasket material may be initially located in the cell, and may be extruded between the anvils

to form the gasket. In another example, the gasket material may be part of a preformed gasket, which may be initially placed between the anvils before pressurization commences.

[0063] In some embodiments, constraining 940 the movement of the gasket material may include moving gasket material over a curved transition region of the anvil and through a narrowing space between anvils. For example, constraining 940 the movement of the gasket material may include moving gasket material over a transition region with a constant radius of curvature, a decreasing radius of curvature, an increasing radius of curvature, or combinations thereof. In other embodiments, constraining 940 the movement of the gasket material may include moving gasket material over a transition region of the anvil with both a curved portion and a planar chamfer portion.

[0064] In some embodiments, compressing 936 the gasket material may include compressing a mold contained within the gasket material. For example, the mold may include one or more cavities having an ultrahard material therein. In at least one embodiment, the mold may be cutting element mold for the production of a cutting element, such as that used in drilling applications. For example, the mold may be a cylindrical mold for a shear cutting element. In other examples, the mold may have a conical portion for a conical cutting element. In yet other examples, the mold may have a curved portion in longitudinal cross-section for a cutting element having a rounded end (e.g., a bullet cutting element). In further examples, the mold may have a peaked portion in longitudinal cross-section for a cutting element having an end with a transverse peak.

[0065] In at least one embodiment, a high pressure press including one or more anvils having a transition region with a curve therein may allow for more stable, more reliable, and faster establishment of a gasket at a periphery of a chamber than a press using a conventional anvil. In a conventional anvil the abrupt changes in angle between the nose and the flank regions can cause a disruption to flow of the gasket material (which although solid, may be thought of as an extremely viscous fluid). Disruption of gasket flow can lead to discontinuous behaviors such as stick-slip and fragmentation of the gasket, which are undesirable. These undesirable behaviors can cause failure of the gasket which adversely affects press operation. An anvil with a curved transition region minimizes obstructions to gasket flow in this region thus achieving a more stable and reliable gasket formation. This

is especially important during decompression from high pressures when the gasket unloads faster than the rest of the high pressure cell.

[0066] Safe and stable decompression requires that the cell extrudes into the gasket controllably which is more easily achieved in a geometry defined by smooth curves. Less gasket failures may increase yield, efficiency, and safety of the high pressure press. In addition, it is believed that an anvil with a surface defined by a smooth curve has a lower stress concentration than one with sharp angles which should improve anvil life in service. A curved transition region will also be less susceptible to damage by edge chipping than a conventional anvil.

[0067] The embodiments of anvils and presses have been primarily described with reference to producing ultrahard materials for wellbore drilling and/or drill bit operations, the anvils and presses described herein may be used in applications other than the production of ultrahard materials.

[0068] The articles “a,” “an,” and “the” are intended to mean that there are one or more of the elements in the preceding descriptions. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to “one embodiment” or “an embodiment” of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. For example, any element described in relation to an embodiment herein may be combinable with any element of any other embodiment described herein. Numbers, percentages, ratios, or other values stated herein are intended to include that value, and also other values that are “about” or “approximately” the stated value, as would be appreciated by one of ordinary skill in the art encompassed by embodiments of the present disclosure. A stated value should therefore be interpreted broadly enough to encompass values that are at least close enough to the stated value to perform a desired function or achieve a desired result. The stated values include at least the variation to be expected in a suitable manufacturing or production process, and may include values that are within 5%, within 1%, within 0.1%, or within 0.01% of a stated value.

[0069] A person having ordinary skill in the art should realize in view of the present disclosure that equivalent constructions do not depart from the spirit and scope of the

present disclosure, and that various changes, substitutions, and alterations may be made to embodiments disclosed herein without departing from the spirit and scope of the present disclosure. Equivalent constructions, including functional “means-plus-function” clauses are intended to cover the structures described herein as performing the recited function, including both structural equivalents that operate in the same manner, and equivalent structures that provide the same function. It is the express intention of the applicant not to invoke means-plus-function or other functional claiming for any claim except for those in which the words ‘means for’ appear together with an associated function. Each addition, deletion, and modification to the embodiments that falls within the meaning and scope of the claims is to be embraced by the claims.

[0070] The terms “approximately,” “about,” and “substantially” as used herein represent an amount close to the stated amount that still performs a desired function or achieves a desired result. For example, the terms “approximately,” “about,” and “substantially” may refer to an amount that is within less than 5% of, within less than 1% of, within less than 0.1% of, and within less than 0.01% of a stated amount. Further, it should be understood that any directions or reference frames in the preceding description are merely relative directions or movements. For example, any references to “up” and “down” or “above” or “below” are merely descriptive of the relative position or movement of the related elements.

[0071] The present disclosure may be embodied in other specific forms without departing from its spirit or characteristics. The described embodiments are to be considered as illustrative and not restrictive. The scope of the disclosure is, therefore, indicated by the appended claims rather than by the foregoing description. Changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

We claim:

1. An anvil for transmitting force in a high pressure press, the anvil comprising:
a body including an ultrahard material, the body having a nose surface, at least one planar flank surface, and a transition region, the nose surface having a nose width, wherein the transition region is located between the nose surface and the at least one planar flank surface, the transition region defining a curve.
2. The anvil of claim 1, the curve having a radius of curvature, wherein the radius of curvature decreases toward the at least one planar flank surface.
3. The anvil of claim 1, the curve having a radius of curvature, wherein the radius of curvature increases toward the at least one planar flank surface.
4. The anvil of claim 1, the body having a longitudinal axis therethrough, and the at least one planar flank surface comprising a plurality of planar flank surfaces positioned at equal angular intervals about the longitudinal axis.
5. The anvil of claim 1, the curve having a constant radius of curvature.
6. The anvil of claim 1, the nose surface being planar.
7. The anvil of claim 1, the curve having a radius of curvature, the radius of curvature and the nose width having a ratio no greater than 1:10.
8. The anvil of claim 1, the transition region including a curved portion and a chamfer portion.

9. A system for applying force, the system comprising:
a plurality of anvils, each of the anvils of the plurality of anvils including:
a body having a nose surface, at least one planar flank surface, and a transition region, the nose surface having a nose width, wherein the transition region is located between the nose surface and the at least one planar flank surface, the transition region defining a curve.
10. The system of claim 9, wherein the plurality of anvils are orthogonally oriented relative to one another.
11. The system of claim 9, further comprising a chamber defined by the nose surface of each of the plurality of anvils.
12. The system of claim 11, a first anvil and a second anvil of the plurality of anvils being adjacent to one another, a space between a first transition region of the first anvil and a second transition region of the second anvil tapering away from the chamber.
13. The system of claim 12, the space between the first transition region and the second transition region having a gasket material positioned therein.
14. The system of claim 12, the space between the first transition region and the second transition region having an initial gasket thickness and a final gasket thickness with a gasket ratio in a range of 1:1.2 to 1:100.
15. The system of claim 11, the chamber having an ultrahard material positioned therein.

16. A method of applying pressure to a chamber; the method comprising:
- compressing the chamber with a plurality of anvils; each anvil of the plurality of anvils having a nose surface, wherein the nose surfaces at least partially define the chamber;
 - flowing a gasket material out of the chamber over a transition region of at least one anvil of the plurality of anvils, the transition region including a curve; and
 - constraining the flow of the gasket material with the curve of the transition region.
17. The method of claim 16, compressing the chamber further comprising compressing a mold positioned in the chamber.
18. The method of claim 17, the mold being a cutting element mold.
19. The method of claim 16, flowing the gasket material further comprising flowing the gasket material between a first transition region of a first anvil of the plurality of anvils and a second transition region of a second anvil of the plurality of anvils, the first transition region having a curve and the second transition region having a curve.
20. The method of claim 16, further including decompressing the chamber.

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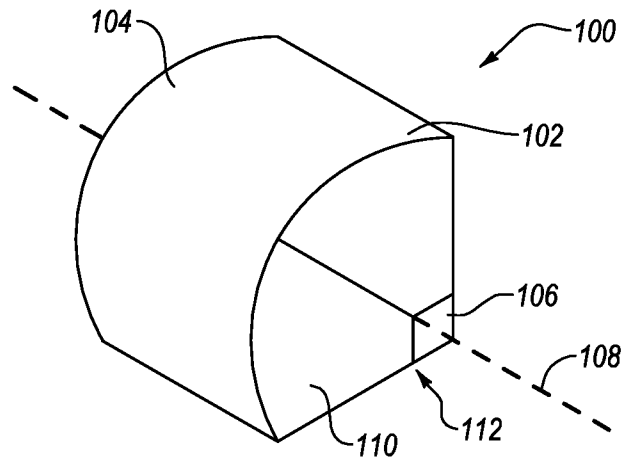


FIG. 1

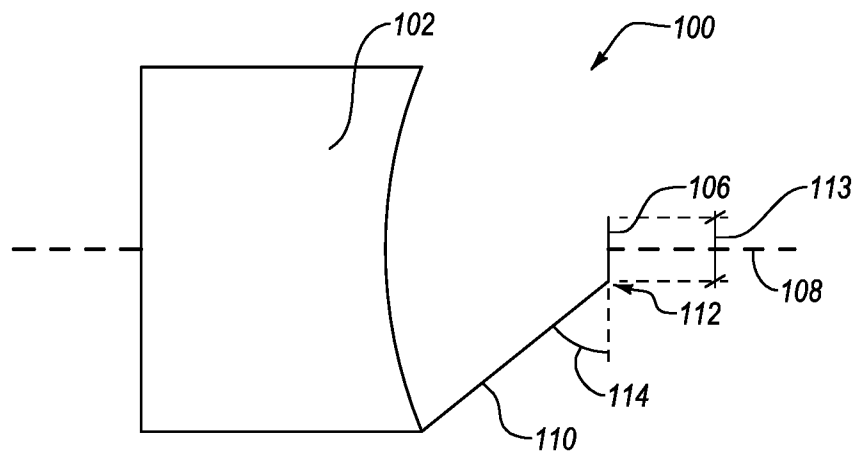


FIG. 2

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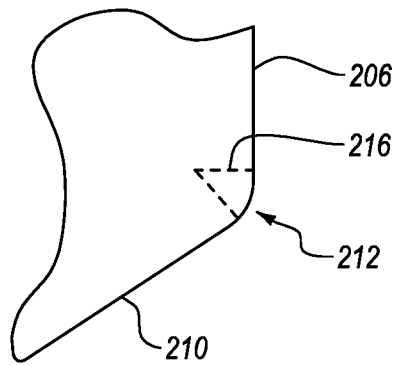


FIG. 3

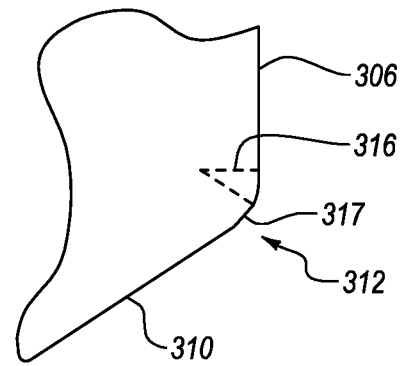


FIG. 4

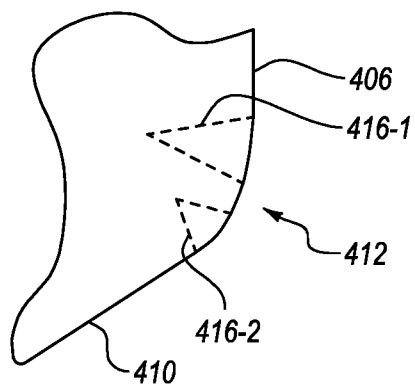


FIG. 5

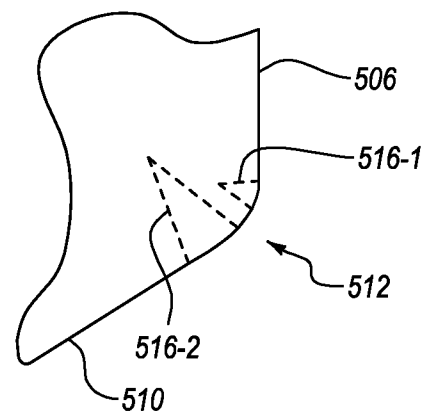


FIG. 6

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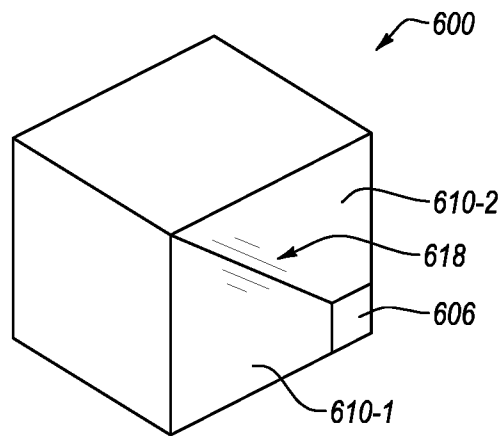


FIG. 7

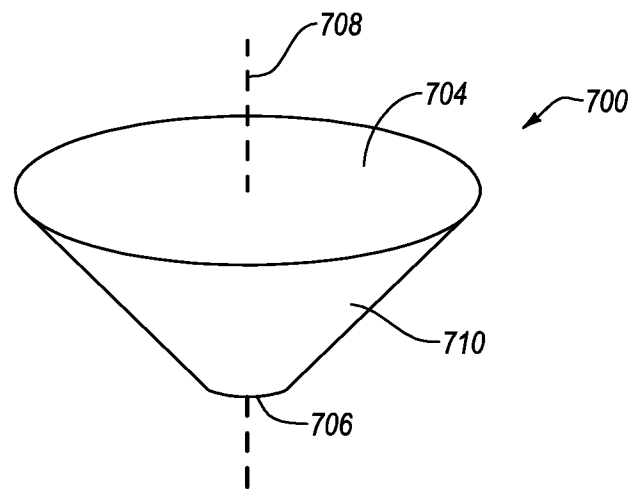


FIG. 8

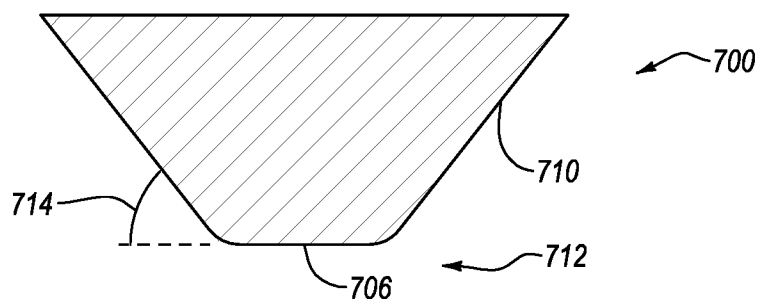


FIG. 9

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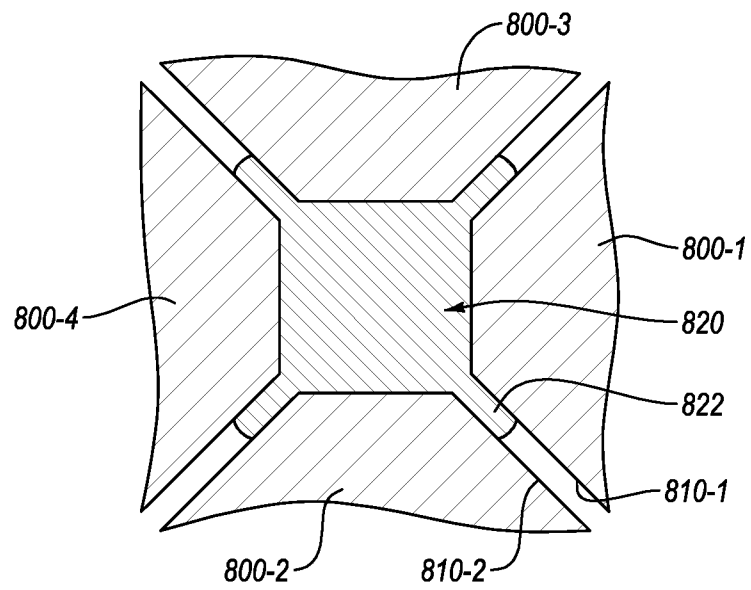


FIG. 10

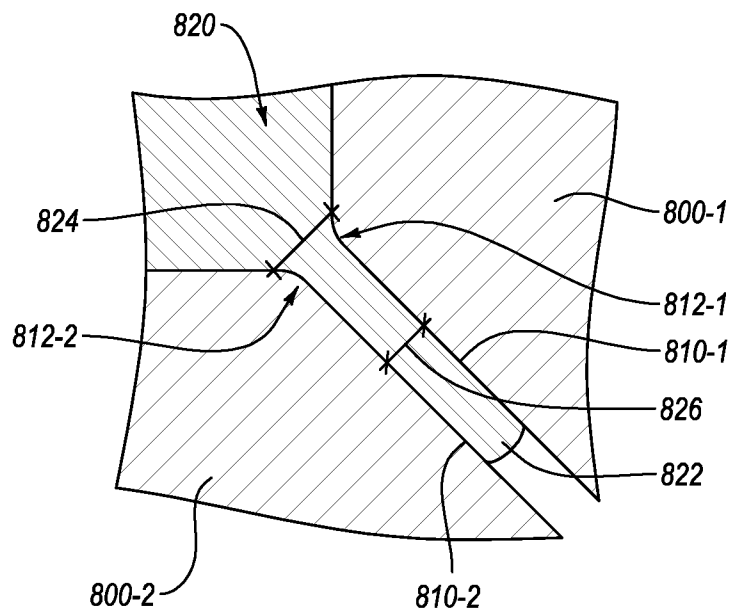
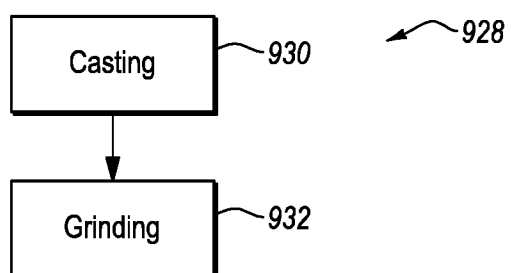
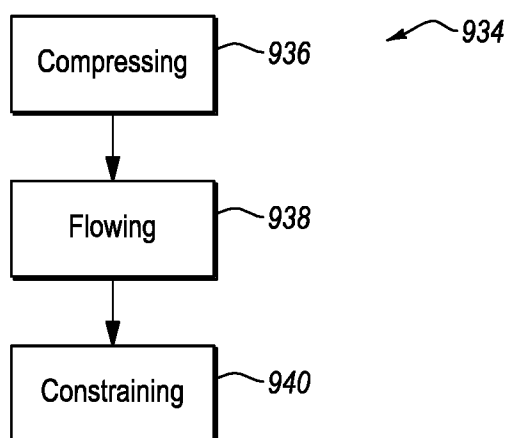


FIG. 11

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**FIG. 12****FIG. 13**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/022400**A. CLASSIFICATION OF SUBJECT MATTER****B01J 3/06(2006.01)i, B01J 3/00(2006.01)i, F16J 12/00(2006.01)i**

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)

B01J 3/06; B23P 11/00; B30B 11/00; B21D 37/04; B30B 1/32; B30B 7/04; B30B 1/00; B01J 3/00; F16J 12/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: anvil, rounded edge, gasket, surface, compress, cubic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102527296 A (JILIN UNIVERSITY) 04 July 2012 See abstract; paragraphs [0025], [0030]; claims 1, 3; and figures 3(a), 3(b).	1-8
Y		9-20
Y	US 2013-0104755 A1 (MIDDLEMISS, STEWART N.) 02 May 2013 See paragraphs [0018]-[0021]; claims 19, 20; and figures 1, 2A.	9-20
A	US 2008-0193581 A1 (HALL, DAVID R. et al.) 14 August 2008 See the entire document.	1-20
A	US 4081505 A (KAWAI, NAOTO) 28 March 1978 See the entire document.	1-20
A	US 5780139 A (CARTER, LAN et al.) 14 July 1998 See the entire document.	1-20

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search

19 June 2017 (19.06.2017)

Date of mailing of the international search report

20 June 2017 (20.06.2017)

Name and mailing address of the ISA/KR

International Application Division

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/022400

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