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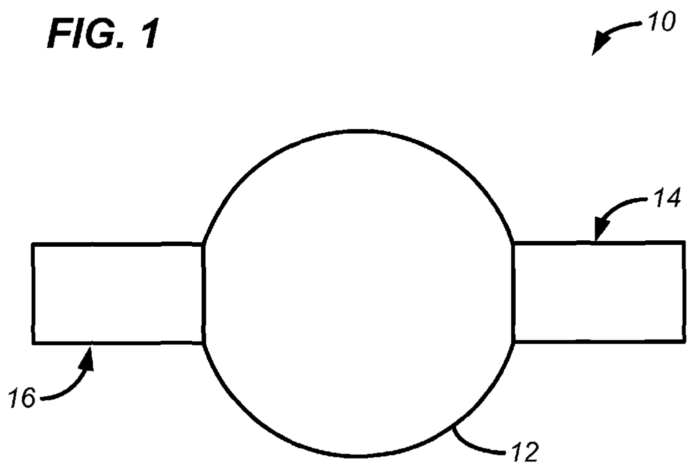
(54) Title: CVT VARIATOR BALL AND METHOD OF CONSTRUCTION THEREOF

FIG. 1



(57) Abstract: Variator balls and methods of manufacturing variator balls are disclosed. Certain methods include projection welding or friction welding a main portion of a spherical body having by a first flat portion to a first axle half shaft, and projection welding or friction welding the main portion of the spherical body having by a second flat portion to a second axle half shaft to form a variator ball. Alternative methods of forming the variator ball includes coupling the main portion of the spherical body to the axle shaft using interference fit processes.

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CVT VARIATOR BALL AND METHOD OF CONSTRUCTION THEREOF

CROSS-REFERENCE

[0001] This application claims the benefit of U.S. Provisional Application No. 61/697,388, filed September 6, 2012 and U.S. Provisional Application No. 61/785,212, filed March 14, 2013, which are incorporated herein by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] A vehicle having a driveline including a tilting ball variator allows an operator of the vehicle or a control system of the vehicle to vary a drive ratio in a stepless manner. A variator is an element of a Continuously Variable Transmission (CVT) or an Infinitely Variable Transmission (IVT). Transmissions that use a variator can decrease the engine's gear ratio as engine speed increases. This keeps the engine within its optimal efficiency while gaining ground speed, or trading speed for hill climbing. Efficiency in this case can be fuel efficiency, decreasing fuel consumption and emissions output, or power efficiency, allowing the engine to produce its maximum power over a wide range of speeds. That is, the variator keeps the engine turning at constant RPMs over a wide range of vehicle speeds.

SUMMARY OF THE INVENTION

[0003] The tilting ball variator includes a first drive ring, a second drive ring, and a plurality of variator balls disposed between the first drive ring and the second drive ring. The plurality of variator balls is simultaneously tilted, which adjusts an axis angle of each of the variator balls, by moving a carrier the plurality of variator balls are rotatably disposed on. The plurality of variator balls are in driving engagement with the first drive ring and the second drive ring through one of a boundary layer type friction and an elastohydrodynamic film. A gear ratio between the carrier (if driven), the first drive ring, and the second drive ring may be adjusted by changing the axis angle of the plurality of variator balls.

[0004] The conventional variator ball includes a perforation therethrough, which passes through a center of the variator ball. The axis and a needle bearing are inserted within the perforation to permit the variator ball to rotate thereabout, and the axis is secured at each end to the carrier. Such an arrangement limits a size of a bearing used, as a size of the perforation must be increased to accommodate a larger bearing. Because the variator balls are in driving engagement with the first drive ring and the second drive ring through one of a boundary layer type friction and an elastohydrodynamic film, precise forming of each of the variator balls is required for the tilting ball variator to operate. The conventional variator ball requires the perforation which is formed therethrough to be aligned with a center of the variator ball very accurately and that the bearing disposed therein have a minimal amount of radial play. Such requirements result in an increased cost of manufacturing of the variator ball, and thus the tilting ball variator the variator ball is incorporated in.

[0005] A variator ball and a method of manufacturing a variator ball is provided herein that facilitates accurate positioning of an axis of the variator ball without increasing a cost of the variator ball.

[0006] Provided herein is a method of manufacturing a variator ball comprising a main portion, a first axle half shaft and a second axle half shaft, the method comprising: creating the main portion of the variator ball by forming a first flat portion on a solid spherical body, and forming a second flat portion on the solid spherical body that is parallel to the first flat portion; attaching the first axle half shaft to the first flat portion; and attaching the second axle half shaft to the second flat portion.

[0007] In some embodiments, the solid spherical body is formed by forging a rough sphere. In some embodiments, the rough sphere comprises steel. In some embodiments, the method comprises improving the spherical accuracy of the rough sphere. In some embodiments, the improving the spherical accuracy of the rough sphere comprises passing the rough sphere through rill plates. In some embodiments, the improving the spherical accuracy of the rough sphere comprises grinding the rough sphere.

[0008] In some embodiments, the method comprises hardening an outer surface of the solid spherical body. In some embodiments, the hardening step comprises carburizing the outer surface of the solid spherical body. In some embodiments, forming the first flat portion comprises removing the hardened outer surface of the solid spherical body such that a non-hardened portion of the solid spherical body is exposed and makes up the center of the first flat portion. In some embodiments, forming the first flat portion and forming the second flat portion comprises grinding opposing portions of the solid spherical body.

[0009] In some embodiments, a first body axis passing through the center of the solid spherical body is orthogonal to the first flat portion. In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion, and aligns with the first body axis. In some embodiments, at least one of the first axle half shaft and the second axle half shaft form an axle axis that aligns with the first body axis.

[0010] In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion. In some embodiments, forming the first flat portion and forming the second flat portion removes a predetermined amount of the spherical body.

[0011] In some embodiments, attaching the first axle half shaft to the first flat portion comprises projection welding the first axle half shaft to the first flat portion. In some embodiments, the first axle half shaft comprises a first axle portion and a first projection.

[0012] In some embodiments, the first axle half shaft is manufactured by forging a roughly formed first axle half shaft and machining or grinding the roughly formed first axle half shaft to increase the accuracy of the first axle portion and/or to refine the shape of the first projection. In some embodiments, the first axle portion is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross section.

[0013] In some embodiments, the first projection has a predetermined cross-sectional area and shape that facilitates forming a projection weld between the first axle half shaft and the first flat portion. In some embodiments, the first projection has a cross-sectional area and shape equal to a cross-sectional area and shape of the first axle portion.

[0014] In some embodiments, projection welding first axle half shaft to the first flat portion comprises

disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the first projection against the first flat portion, aligning the main portion with the first axle half shaft, contacting a second welding terminal to the first axle portion which, thereby, is in electrical communication therewith, applying force to the first axle portion against the first flat portion, and passing an electrical current from the second welding terminal to the first welding terminal through the first axle half shaft and the main portion, thereby causing the first projection to increase to a welding temperature.

[0015] In some embodiments, projection welding first axle half shaft to the first flat portion comprises disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the first projection against the first flat portion, aligning the main portion with the first axle half shaft, contacting a second welding terminal to the first axle portion, which, thereby, is in electrical communication therewith, applying force to the first axle portion against the first flat portion, and passing an electrical current from the first welding terminal to the second welding terminal through the first axle half shaft and the main portion, thereby causing the first projection to increase to a welding temperature.

[0016] In some embodiments, the electrical current increases the first flat portion to the welding temperature. In some embodiments, the force applied by the second welding terminal causes the first projection to deform and spread between the first flat portion and the first axle portion to form a projection weld.

[0017] In some embodiments, the method comprises stopping the electrical current after moving the first axle half shaft a predetermined distance toward the main portion. In some embodiments, the method comprises stopping the electrical current after applying a predetermined amount of the force for a predetermined time.

[0018] In some embodiments, the aligning the main portion with the first axle half shaft uses an alignment tool.

[0019] In some embodiments, the method comprises attaching the second axle half shaft to the second flat portion comprises projection welding the second axle half shaft to the second flat portion. In some embodiments, the second axle half shaft comprises a second axle portion and a second projection. In some embodiments, the second axle half is manufactured by forging a roughly formed second axle half and machining or grinding the roughly formed second axle half to increase the accuracy of the second axle portion and/or to refine the shape of the second projection.

[0020] In some embodiments, the second axle portion is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross-section. In some embodiments, the second projection has a predetermined cross-sectional area and shape that facilitates forming a projection weld between the second axle half shaft and the second flat portion. In some embodiments, the second projection has a cross-sectional area and shape equal to a cross-sectional area and shape of the second axle portion.

[0021] In some embodiments, projection welding second axle half shaft to the second flat portion comprises disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the second projection against the second flat portion, aligning the main portion with the second axle half shaft, contacting a second welding terminal to the second axle portion, which, thereby, is in electrical communication therewith, applying force to the second axle portion against the first flat portion, and passing an electrical current from the second welding terminal to the first welding terminal through the second axle half shaft and the main portion, thereby causing the second projection to increase to a welding temperature.

[0022] In some embodiments, projection welding second axle half shaft to the second flat portion comprises disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the second projection against the second flat portion, aligning the main portion with the second axle half shaft, contacting a second welding terminal to the second axle portion, which, thereby, is in electrical communication therewith, applying force to the second axle portion against the second flat portion, and passing an electrical current from the first welding terminal to the second welding terminal through the second axle half shaft and the main portion, thereby causing the second projection to increase to a welding temperature.

[0023] In some embodiments, the electrical current increases the second flat portion to the welding temperature. In some embodiments, the force applied by the second welding terminal causes the second projection to deform and spread between the second flat portion and the second axle portion to form a projection weld.

[0024] In some embodiments, the method comprises stopping the electrical current after moving the second axle half shaft a predetermined distance toward the main portion. In some embodiments, the method comprises stopping the electrical current after applying a predetermined amount of the force for a predetermined time.

[0025] In some embodiments, aligning the main portion with the second axle half shaft uses an alignment tool.

[0026] In some embodiments, attaching the first axle half shaft to the first flat portion comprises friction welding the first axle half shaft to the first flat portion. In some embodiments, friction welding first axle half shaft to the first flat portion comprises holding the main portion stationary, rotating the first axle half shaft, pressing a first portion of the rotating first axle half shaft against first flat portion, thereby generating heat from the friction between the first portion of the first axle half shaft and the first flat portion that heats the first portion and the first flat portion to a welding temperature, and stopping the rotation of the first axle half shaft once the welding temperature is reached.

[0027] In some embodiments, friction welding first axle half shaft to the first flat portion comprises holding the first axle half shaft stationary, rotating the main portion, pressing a first portion of the first axle half shaft against first flat portion, thereby generating heat from the friction between the first portion of the first axle half shaft and the first flat portion that heats the first portion and the first flat portion to a welding temperature, and stopping the rotation of the main portion once the welding temperature is reached.

[0028] In some embodiments, attaching the second axle half shaft to the second flat portion comprises friction welding the second axle half shaft to the second flat portion. In some embodiments, friction welding second axle half shaft to the second flat portion comprises holding the main portion stationary, rotating the second axle half shaft, pressing a second portion of the rotating second axle half shaft against second flat portion, thereby generating heat from the friction between the second portion of the second axle half shaft and the second flat portion that heats the second portion and the second flat portion to a welding temperature, and stopping the rotation of the second axle half shaft once the welding temperature is reached.

[0029] In some embodiments, friction welding second axle half shaft to the second flat portion comprises holding the second axle half shaft stationary, rotating the main portion, pressing a second portion of the second axle half shaft against second flat portion, thereby generating heat from the friction between the second portion of the second axle half shaft and the second flat portion that heats the second portion and the second flat portion to a welding temperature, and stopping the rotation of the main portion once the welding temperature is reached.

[0030] In some embodiments, the method comprises simultaneously attaching the first axle half shaft to the first flat portion and attaching the second axle half shaft to the second flat portion using friction welding.

[0031] In some embodiments, the method comprises sequentially attaching the first axle half shaft to the first flat portion using friction welding and then attaching the second axle half shaft to the second flat portion using friction welding.

[0032] In some embodiments, the method comprises simultaneously attaching the first axle half shaft to the first flat portion and attaching the second axle half shaft to the second flat portion using projection welding.

[0033] In some embodiments, the method comprises sequentially attaching the first axle half shaft to the first flat portion using projection welding and then attaching the second axle half shaft to the second flat portion using projection welding.

[0034] In some embodiments, attaching the axle half shaft to the second flat portion comprises friction welding the second axle half shaft to the second flat portion.

[0035] Provided herein is a method of manufacturing a variator ball comprising a main portion and an axle shaft having a first end portion, a second end portion and a center portion, the method comprising: creating a perforation through the center of a solid spherical body to form the main portion of the variator ball; and coupling the axle shaft using an interference fit process comprising heating the main portion sufficiently to increase the size of the perforation in the main portion, aligning the axle shaft with the perforation, or aligning the perforation with the axle shaft, pressing the axle shaft through the perforation, and decreasing the temperature the main portion, or allowing said main portion to decrease in temperature.

[0036] Provided herein is a method of manufacturing a variator ball comprising a main portion and an axle shaft having a first end portion, a second end portion and a center portion, the method comprising: creating a perforation through the center of a solid spherical body to form the main portion of the variator ball; and coupling the axle shaft using an interference fit process comprising cooling the axle shaft sufficiently to decrease the size of a diameter of the axle shaft, aligning the axle shaft with the perforation, or aligning the perforation with the axle shaft pressing the axle shaft through the perforation, and increasing the temperature the axle shaft, or allowing said axle shaft to increase in temperature.

[0037] In some embodiments, the method comprises cooling the axle shaft sufficiently to decrease the size of a diameter of the axle shaft prior to pressing the axle shaft into the perforation, and subsequently increasing the temperature the axle shaft or allowing said axle shaft to increase in temperature.

[0038] In some embodiments, the method comprises: forming a first flat portion on the solid spherical body; and forming a second flat portion on the solid spherical body that is parallel to the first flat portion, wherein the perforation is created through the first flat portion and the second flat portion.

[0039] In some embodiments, the solid spherical body is formed by forging a rough sphere. In some embodiments, the rough sphere comprises steel. In some embodiments, the method comprises improving the spherical accuracy of the rough sphere. In some embodiments, improving the spherical accuracy of the rough sphere comprises passing the rough sphere through rill plates. In some embodiments, the improving the spherical accuracy of the rough sphere comprises grinding the rough sphere.

[0040] In some embodiments, the method comprises hardening an outer surface of the solid spherical body. In some embodiments, the hardening step comprises carburizing the outer surface of the solid spherical body. In some embodiments, the method comprises hardening an outer surface of the solid spherical body wherein forming the first flat portion comprises removing the hardened outer surface of the solid spherical body such that a non-hardened portion of the solid spherical body is exposed and makes up the center of the first flat portion.

[0041] In some embodiments, forming the first flat portion and forming the second flat portion comprises grinding opposing portions of the solid spherical body.

[0042] In some embodiments, a first body axis passing through the center of the solid spherical body is orthogonal to the first flat portion. In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion, and aligns with the first body axis. In some embodiments, the axle shaft forms an axle axis that aligns with the first body axis.

[0043] In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion. In some embodiments, forming the first flat portion and forming the second flat portion removes a predetermined amount of the spherical body.

[0044] In some embodiments, the axle shaft is solid. In some embodiments, the axle shaft is a solid cylindrical member. In some embodiments, the axle shaft comprises a shape that is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross section. In some embodiments, the perforation shape aligns with the shape of the axle shaft.

[0045] In some embodiments, the axle shaft is forging from steel. In some embodiments, the method comprises refining the axle shaft shape by grinding or machining the axle shaft. In some embodiments, at least two of a first end portion diameter of the first end portion, a center portion diameter of the center portion, and a second end portion diameter of the second end portion are substantially equal to one another. In some embodiments, all three of the first end portion diameter, the center portion diameter, and the second end portion diameter are substantially equal to one another. In some embodiments, at least one of a first end portion shape of the first end portion, a center portion shape of the center portion, and a second end portion shape of the second end portion is different than another of the first end portion shape, the center portion shape, and the second end portion shape.

[0046] In some embodiments, the method comprises pressing the axle shaft through the perforation a predetermined distance, or using a predetermined rate for a predetermined time. In some embodiments, the method comprises using an alignment device to press the axle shaft through the perforation, wherein the alignment device allows for control of the distance, rate, time, or any combination thereof.

[0047] Provided herein are also method s of manufacturing a variator ball comprising a spherical body, a first axle half shaft and a second axle half shaft, the method comprising: attaching the first axle half shaft to the spherical body of the variator ball by friction welding or projection welding, and attaching the second axle half shaft to the spherical body of the variator ball by friction welding or projection welding.

[0048] In some embodiments, the methods described herein further comprise hardening an outer surface of the variator ball. In some embodiments, the hardening step comprises carburizing the outer surface of the variator ball.

[0049] In some embodiments, the methods described herein comprise sorting or manufacturing the variator ball to be: within a 0.001 inch range around a target dimension of said ball, within a 0.0005 inch range around a target dimension of said ball, or within a 0.0001 inch range around a target dimension of said ball. In some embodiments, the target dimension of said ball is a diameter of said ball.

[0050] In some embodiments, the methods described herein comprise sorting or manufacturing the first axle half shaft to be: within a 0.001 inch range around a target dimension of said first axle half shaft, within a 0.0005 inch range around a target dimension of said first axle half shaft, or within a 0.0001 inch range around a target dimension of said first axle half shaft. In some embodiments, the target dimension of said first axle half shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said first axle half shaft.

[0051] In some embodiments, the methods described herein comprise sorting or manufacturing the second axle half shaft to be: within a 0.001 inch range around a target dimension of said second axle half shaft, within a 0.0005 inch range around a target dimension of said second axle half shaft, or within a 0.0001 inch range around a target dimension of said second axle half shaft. In some embodiments, the target dimension of said second axle half shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said second axle half shaft.

[0052] In some embodiments, the methods described herein comprise sorting or manufacturing the axle shaft to be: within a 0.001 inch range around a target dimension of said axle shaft, within a 0.0005 inch range around a target dimension of said axle shaft, or within a 0.0001 inch range around a target dimension of said axle shaft. In some embodiments, the target dimension of said axle shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said axle shaft.

[0053] Provided herein is a variator ball comprising a main portion, a first axle half shaft and a second axle half shaft manufactured by any one of the methods described herein. Provided herein is a variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein.

[0054] Provided herein is a variable transmission comprising the variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein. In some embodiments, the variable transmission comprises a traction fluid.

[0055] Provided herein is a vehicle driveline comprising an engine, a variable transmission comprising the variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein, and a vehicle output.

[0056] Provided herein is a vehicle comprising the variable transmission comprising a variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein.

[0057] Provided herein is a manufacturing apparatus that implements any of the methods described herein in full or in part, or according to methods obvious to one of skill in the art upon reading the disclosure herein.

[0058] Provided herein is a variator ball comprising a spherical ball, a first axle half shaft and a second axle half shaft manufactured by any one of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein.

INCORPORATION BY REFERENCE

[0059] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0060] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0061] Figure 1 depicts an embodiment of a variator ball.

[0062] Figure 2 depicts an embodiment of the main portion of an embodiment variator ball.

[0063] Figure 3 depicts an embodiment of the first axle half shaft and the second axle half shaft.

[0064] Figure 4 depicts a cross sectional view of an embodiment of the variator ball having the first axle half shaft and the second axle shaft coupled to the main portion.

[0065] Figure 5 depicts an embodiment of a variator ball having an axle shaft coupled to the main portion with an interference fit.

[0066] Figure 6 depicts an embodiment of the main portion of a variator ball having an axle shaft coupled to the main portion with an interference fit.

[0067] Figure 7 depicts an embodiment of the axle shaft of a variator ball wherein the axle shaft is coupled to the main portion with an interference fit.

[0068] Figure 8 depicts a cross-sectional view of an embodiment of a variator ball of Figure 5 having the axle shaft coupled to the main portion.

DETAILED DESCRIPTION OF THE INVENTION

[0069] The conventional variator ball includes a perforation therethrough, which passes through a center of the variator ball. The axis and a needle bearing are inserted within the perforation to permit the variator ball to rotate thereabout, and the axis is secured at each end to the carrier. Such an arrangement limits a size of a bearing used, as a size of the perforation must be increased to accommodate a larger bearing. Because the variator balls are in driving engagement with the first drive ring and the second drive ring through one of a boundary layer type friction and an elastohydrodynamic film, precise forming of each of the variator balls is required for the tilting ball variator to operate. The conventional variator ball requires the perforation which is formed therethrough to be aligned with a center of the variator ball very accurately and that the bearing disposed therein have a minimal amount of radial play. Such requirements result in an increased cost of manufacturing of the variator ball, and thus the tilting ball variator the variator ball is incorporated in.

[0070] Certain variator (CVP) embodiments of a variable transmission work with a traction fluid (or lubricant). The lubricant between the ball and the rings (first ring assembly or second ring assembly) acts as a solid at high pressure, transferring the power from the first ring assembly, through the variator balls, to the second ring assembly. By tilting the variator balls' axes, the ratio can be changed between input and output. When the axis of each of the variator balls is horizontal the ratio is one. When the axis is tilted, the distance between the axis and the contact point change, thus modifying the overall ratio. All the variator balls'axles are tilted at the same time with a mechanism included in the cage.

[0071] A variator ball and a method of manufacturing a variator ball is provided herein that facilitates accurate positioning of an axis of the variator ball without increasing a cost of the variator ball.

[0072] Provided herein is a method of manufacturing a variator ball comprising a main portion, a first axle half shaft and a second axle half shaft, the method comprising: creating the main portion of the variator ball by forming a first flat portion on a solid spherical body, and forming a second flat portion on the solid spherical body that is parallel to the first flat portion; attaching the first axle half shaft to the first flat portion; and attaching the second axle half shaft to the second flat portion.

[0073] In some embodiments, the solid spherical body is formed by forging a rough sphere. In some embodiments, the rough sphere comprises steel. In some embodiments, the method comprises improving the spherical accuracy of the rough sphere. In some embodiments, the improving the spherical accuracy of the rough sphere comprises passing the rough sphere through rill plates. In some embodiments, the improving the spherical accuracy of the rough sphere comprises grinding the rough sphere.

[0074] In some embodiments, the method comprises hardening an outer surface of the solid spherical body. In some embodiments, the hardening step comprises carburizing the outer surface of the solid spherical body. In some embodiments, forming the first flat portion comprises removing the hardened outer surface of the solid spherical body such that a non-hardened portion of the solid spherical body is exposed and makes up the center of the first flat portion. In some embodiments, forming the first flat portion and forming the second flat portion comprises grinding opposing portions of the solid spherical body.

[0075] In some embodiments, a first body axis passing through the center of the solid spherical body is orthogonal to the first flat portion. In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion, and aligns with the first body axis. In some embodiments, at least one of the first axle half shaft and the second axle half shaft form an axle axis that aligns with the first body axis.

[0076] In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion. In some embodiments, forming the first flat portion and forming the second flat portion removes a predetermined amount of the spherical body.

[0077] In some embodiments, attaching the first axle half shaft to the first flat portion comprises projection welding the first axle half shaft to the first flat portion. In some embodiments, the first axle half shaft comprises a first axle portion and a first projection.

[0078] In some embodiments, the first axle half shaft is manufactured by forging a roughly formed first axle half shaft and machining or grinding the roughly formed first axle half shaft to increase the accuracy of the first axle portion and/or to refine the shape of the first projection. In some embodiments, the first axle portion is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross section.

[0079] In some embodiments, the first projection has a predetermined cross-sectional area and shape that facilitates forming a projection weld between the first axle half shaft and the first flat portion. In some embodiments, the first projection has a cross-sectional area and shape equal to a cross-sectional area and shape of the first axle portion.

[0080] In some embodiments, projection welding first axle half shaft to the first flat portion comprises

disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the first projection against the first flat portion, aligning the main portion with the first axle half shaft, contacting a second welding terminal to the first axle portion which, thereby, is in electrical communication therewith, applying force to the first axle portion against the first flat portion, and passing an electrical current from the second welding terminal to the first welding terminal through the first axle half shaft and the main portion, thereby causing the first projection to increase to a welding temperature.

[0081] In some embodiments, projection welding first axle half shaft to the first flat portion comprises disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the first projection against the first flat portion, aligning the main portion with the first axle half shaft, contacting a second welding terminal to the first axle portion, which, thereby, is in electrical communication therewith, applying force to the first axle portion against the first flat portion, and passing an electrical current from the first welding terminal to the second welding terminal through the first axle half shaft and the main portion, thereby causing the first projection to increase to a welding temperature.

[0082] In some embodiments, the electrical current increases the first flat portion to the welding temperature. In some embodiments, the force applied by the second welding terminal causes the first projection to deform and spread between the first flat portion and the first axle portion to form a projection weld.

[0083] In some embodiments, the method comprises stopping the electrical current after moving the first axle half shaft a predetermined distance toward the main portion. In some embodiments, the method comprises stopping the electrical current after applying a predetermined amount of the force for a predetermined time.

[0084] In some embodiments, the aligning the main portion with the first axle half shaft uses an alignment tool.

[0085] In some embodiments, the method comprises attaching the second axle half shaft to the second flat portion comprises projection welding the second axle half shaft to the second flat portion. In some embodiments, the second axle half shaft comprises a second axle portion and a second projection. In some embodiments, the second axle half is manufactured by forging a roughly formed second axle half and machining or grinding the roughly formed second axle half to increase the accuracy of the second axle portion and/or to refine the shape of the second projection.

[0086] In some embodiments, the second axle portion is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross-section. In some embodiments, the second projection has a predetermined cross-sectional area and shape that facilitates forming a projection weld between the second axle half shaft and the second flat portion. In some embodiments, the second projection has a cross-sectional area and shape equal to a cross-sectional area and shape of the second axle portion.

[0087] In some embodiments, projection welding second axle half shaft to the second flat portion comprises disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the second projection against the second flat portion, aligning the main portion with the second axle half shaft, contacting a second welding terminal to the second axle portion, which, thereby, is in electrical communication therewith, applying force to the second axle portion against the first flat portion, and passing an electrical current from the second welding terminal to the first welding terminal through the second axle half shaft and the main portion, thereby causing the second projection to increase to a welding temperature.

[0088] In some embodiments, projection welding second axle half shaft to the second flat portion comprises disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith, disposing the second projection against the second flat portion, aligning the main portion with the second axle half shaft, contacting a second welding terminal to the second axle portion, which, thereby, is in electrical communication therewith, applying force to the second axle portion against the second flat portion, and passing an electrical current from the first welding terminal to the second welding terminal through the second axle half shaft and the main portion, thereby causing the second projection to increase to a welding temperature.

[0089] In some embodiments, the electrical current increases the second flat portion to the welding temperature. In some embodiments, the force applied by the second welding terminal causes the second projection to deform and spread between the second flat portion and the second axle portion to form a projection weld.

[0090] In some embodiments, the method comprises stopping the electrical current after moving the second axle half shaft a predetermined distance toward the main portion. In some embodiments, the method comprises stopping the electrical current after applying a predetermined amount of the force for a predetermined time.

[0091] In some embodiments, aligning the main portion with the second axle half shaft uses an alignment tool.

[0092] In some embodiments, attaching the first axle half shaft to the first flat portion comprises friction welding the first axle half shaft to the first flat portion. In some embodiments, friction welding first axle half shaft to the first flat portion comprises holding the main portion stationary, rotating the first axle half shaft, pressing a first portion of the rotating first axle half shaft against first flat portion, thereby generating heat from the friction between the first portion of the first axle half shaft and the first flat portion that heats the first portion and the first flat portion to a welding temperature, and stopping the rotation of the first axle half shaft once the welding temperature is reached.

[0093] In some embodiments, friction welding first axle half shaft to the first flat portion comprises holding the first axle half shaft stationary, rotating the main portion, pressing a first portion of the first axle half shaft against first flat portion, thereby generating heat from the friction between the first portion of the first axle half shaft and the first flat portion that heats the first portion and the first flat portion to a welding temperature, and stopping the rotation of the main portion once the welding temperature is reached.

[0094] In some embodiments, attaching the second axle half shaft to the second flat portion comprises friction welding the second axle half shaft to the second flat portion. In some embodiments, friction welding second axle half shaft to the second flat portion comprises holding the main portion stationary, rotating the second axle half shaft, pressing a second portion of the rotating second axle half shaft against second flat portion, thereby generating heat from the friction between the second portion of the second axle half shaft and the second flat portion that heats the second portion and the second flat portion to a welding temperature, and stopping the rotation of the second axle half shaft once the welding temperature is reached.

[0095] In some embodiments, friction welding second axle half shaft to the second flat portion comprises holding the second axle half shaft stationary, rotating the main portion, pressing a second portion of the second axle half shaft against second flat portion, thereby generating heat from the friction between the second portion of the second axle half shaft and the second flat portion that heats the second portion and the second flat portion to a welding temperature, and stopping the rotation of the main portion once the welding temperature is reached.

[0096] In some embodiments, the method comprises simultaneously attaching the first axle half shaft to the first flat portion and attaching the second axle half shaft to the second flat portion using friction welding.

[0097] In some embodiments, the method comprises sequentially attaching the first axle half shaft to the first flat portion using friction welding and then attaching the second axle half shaft to the second flat portion using friction welding.

[0098] In some embodiments, the method comprises simultaneously attaching the first axle half shaft to the first flat portion and attaching the second axle half shaft to the second flat portion using projection welding.

[0099] In some embodiments, the method comprises sequentially attaching the first axle half shaft to the first flat portion using projection welding and then attaching the second axle half shaft to the second flat portion using projection welding.

[00100] In some embodiments, attaching the axle half shaft to the second flat portion comprises friction welding the second axle half shaft to the second flat portion.

[00101] FIG. 1 illustrates a variator ball 10 according to an embodiment of the invention. The variator ball 10 comprises a main portion 12, a first axle half shaft 14, and a second axle half shaft 16. The first axle shaft 14 and the second axle half shaft 16 are projection welded to the main portion 12.

[00102] FIG. 2 illustrates the main portion 12. The main portion 12 is a solid spherical body having two flats 18 opposingly formed thereon. The main portion 12 may be formed using a multi-step process. First, a rough sphere is formed from a steel using a forging process. Next, the rough sphere is refined through a grinding process which typically includes passing the rough sphere through rill plates to increase its spherical accuracy. Once the rough sphere has been sufficiently refined through grinding, the resulting sphere is hardened. An outer surface of the sphere is hardened using a carburizing process; however, it is understood that other hardening processes may be used. Lastly, opposing portions of the sphere are ground to form the flats 18. The grinding process removes the hardened outer surface of the sphere. The flats 18 are parallel to one another and a predetermined amount of the sphere is precisely removed during the grinding process to complete the forming of the main portion 12.

[00103] FIG. 3 illustrates the first axle half shaft 14 and the second axle half shaft 16. As illustrated, the first axle half shaft 14 and the second axle half shaft 16 are identical, and thus the process to form each is identical; however, it is understood that the process may be adapted where the first axle half shaft 14 and the second axle half shaft 16 are not identical. Each of the first axle half shaft 14 and the second axle half shaft 16 include an axle portion 20 and a projection 22. The first axle half shaft 14 and the second axle half shaft 16 may be formed using a multi-step process. First, the first axle half shaft 14 and the second axle half shaft 16 may be roughly formed from a steel using a forging process. Next, the first axle half shaft 14 and the second axle half shaft 16 may be refined through a machining or a grinding process to increase an accuracy of the axle portion 20 or to refine a shape of the projection 22.

[00104] The axle portion 20 is an elongate cylindrical portion of the first axle half shaft 14 and the second axle half shaft 16. The axle portion 20 may act as an inner race for a bearing (not shown) which is disposed about the axle portion 20. As shown in FIG. 3, the axle portion 20 is cylindrical in shape; however, it is understood that the axle portion 20 may have other shapes.

[00105] The projection 22 is a portion of the first axle half shaft 14 and the second axle half shaft 16 extending from the axle portion 20; however, it is understood that the projection 22 may be indistinguishable from the axle portion 20. The projection 22 has a predetermined cross-sectional area and shape that facilitates forming a projection weld between the first axle half shaft 14 or the second axle half shaft 16 and the flats 18
of the main portion 12; however, it is understood that the projection 22 may have a cross-sectional area and shape equal to a cross-sectional area and shape of the axle portion 20.

[00106] As mentioned hereinabove, to form the variator ball 10, the first axle half shaft 14 and the second axle half shaft 16 are projection welded to the flats 18 of the main portion 12. The main portion 12 is disposed against a first welding terminal (not shown) and is in electrical communication therewith. The projection 22 of the first axle half shaft 14 is disposed against the flat 18. An alignment device (not shown) is used to accurately align the main portion 12 with the first axle half shaft 14. A second welding terminal (not shown), which may be moved by an operator, is moved to contact and apply a force to the axle portion 20 of the first axle half shaft 14. Simultaneously, the second welding terminal comes into electrical communication with the axle portion 20 of the first axle half shaft 14. An electrical current passes from the second welding terminal to the first welding terminal, through the first axle half shaft 14 and the main portion 12, which causes the projection 22 to increase to a welding temperature. Alternately, it is understood that the electrical current may pass from the first welding terminal to the second welding terminal. Because the projection 22 is in contact with the flat 18, the flat also increases to the welding temperature. As the projection 22 approaches the welding temperature, the force applied by the second welding terminal causes the projection 22 to deform, and the projection 22 is spread between the flat 18 and the axle portion 20 of the first axle half shaft 14 to form a weld. When the first axle half shaft 14 has moved a predetermined amount towards the main portion 12 or a predetermined amount of time has passed, the electrical current is stopped and the second welding terminal is moved away from and out of contact with the first axle half shaft 14. Once the weld has cooled, the first axle half shaft 14 is coupled to the main portion 12.

[00107] The second axle half shaft 16 is coupled to the main portion 12 in a substantially similar manner. An alignment device (not shown) used to align the second axle half shaft 16 with the flat 18 of the main portion 12 differs from the alignment device used to align the first axle half shaft 14 in that it must accommodate for the first axle half shaft 14 being coupled to the main portion 12. FIG. 4 is a cross sectional view of the variator ball 10 having the first axle half shaft 14 and the second axle shaft 16 coupled to the main portion 12. Further, it is understood that the first axle half shaft 14 and the second axle half shaft 16 may be simultaneously welded to the flats 18 of the main portion 12 by adapting the projection welding process as described above.

[00108] Alternately, the first axle half shaft 14 and the second axle half shaft 16 may be welded to the main portion 12 using friction welding. To friction weld the first axle half shaft 14 and the second axle half shaft 16 to the main portion 12, the main portion 12 is held in a stationary position and the first axle half shaft 14 and the second axle half shaft 16 are rotated and pressed against the flats 18. Each of the first axle half shaft 14 and the second axle half shaft 16 may be friction welded to the main portion 12 individually or simultaneously. Friction generated between the first axle half shaft 14 and the second axle half shaft 16 and each of the flats 18 heats a portion of the first axle half shaft 14 and the second axle half shaft 16 and a portion of the main portion 12 to a welding temperature. Once the welding temperature is reached, rotation between the first axle half shaft 14 or the second axle half shaft 16 and the main portion 12 is stopped, which allows the portion of the first axle half shaft 14 or the second axle half shaft 16 and the portion of the main portion 12 to cool from a welding temperature, coupling the first axle half shaft 14 or the second axle half shaft 16 to the main portion12.

[00109] Provided herein is a method of manufacturing a variator ball comprising a main portion and an axle shaft having a first end portion, a second end portion and a center portion, the method comprising: creating a perforation through the center of a solid spherical body to form the main portion of the variator ball; and coupling the axle shaft using an interference fit process comprising heating the main portion sufficiently to increase the size of the perforation in the main portion, aligning the axle shaft with the perforation, or aligning the perforation with the axle shaft, pressing the axle shaft through the perforation, and decreasing the temperature the main portion, or allowing said main portion to decrease in temperature.

[00110] Provided herein is a method of manufacturing a variator ball comprising a main portion and an axle shaft having a first end portion, a second end portion and a center portion, the method comprising: creating a perforation through the center of a solid spherical body to form the main portion of the variator ball; and coupling the axle shaft using an interference fit process comprising cooling the axle shaft sufficiently to decrease the size of a diameter of the axle shaft, aligning the axle shaft with the perforation, or aligning the perforation with the axle shaft pressing the axle shaft through the perforation, and increasing the temperature the axle shaft, or allowing said axle shaft to increase in temperature.

[00111] In some embodiments, the method comprises cooling the axle shaft sufficiently to decrease the size of a diameter of the axle shaft prior to pressing the axle shaft into the perforation, and subsequently increasing the temperature the axle shaft or allowing said axle shaft to increase in temperature.

[00112] In some embodiments, the method comprises: forming a first flat portion on the solid spherical body; and forming a second flat portion on the solid spherical body that is parallel to the first flat portion, wherein the perforation is created through the first flat portion and the second flat portion.

[00113] In some embodiments, the solid spherical body is formed by forging a rough sphere. In some embodiments, the rough sphere comprises steel. In some embodiments, the method comprises improving the spherical accuracy of the rough sphere. In some embodiments, improving the spherical accuracy of the rough sphere comprises passing the rough sphere through rill plates. In some embodiments, the improving the spherical accuracy of the rough sphere comprises grinding the rough sphere.

[00114] In some embodiments, the method comprises hardening an outer surface of the solid spherical body. In some embodiments, the hardening step comprises carburizing the outer surface of the solid spherical body. In some embodiments, the method comprises hardening an outer surface of the solid spherical body wherein forming the first flat portion comprises removing the hardened outer surface of the solid spherical body such that a non-hardened portion of the solid spherical body is exposed and makes up the center of the first flat portion.

[00115] In some embodiments, forming the first flat portion and forming the second flat portion comprises grinding opposing portions of the solid spherical body.

[00116] In some embodiments, a first body axis passing through the center of the solid spherical body is orthogonal to the first flat portion. In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion, and aligns with the first body axis. In some embodiments, the axle shaft forms an axle axis that aligns with the first body axis.

[00117] In some embodiments, a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion. In some embodiments, forming the first flat portion and forming the second flat portion removes a predetermined amount of the spherical body.

[00118] In some embodiments, the axle shaft is solid. In some embodiments, the axle shaft is a solid cylindrical member. In some embodiments, the axle shaft comprises a shape that is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross section. In some embodiments, the perforation shape aligns with the shape of the axle shaft.

[00119] In some embodiments, the axle shaft is forging from steel. In some embodiments, the method comprises refining the axle shaft shape by grinding or machining the axle shaft. In some embodiments, at least two of a first end portion diameter of the first end portion, a center portion diameter of the center portion, and a second end portion diameter of the second end portion are substantially equal to one another. In some embodiments, all three of the first end portion diameter, the center portion diameter, and the second end portion diameter are substantially equal to one another. In some embodiments, at least one of a first end portion shape of the first end portion, a center portion shape of the center portion, and a second end portion shape of the second end portion is different than another of the first end portion shape, the center portion shape, and the second end portion shape.

[00120] In some embodiments, the method comprises pressing the axle shaft through the perforation a predetermined distance, or using a predetermined rate for a predetermined time. In some embodiments, the method comprises using an alignment device to press the axle shaft through the perforation, wherein the alignment device allows for control of the distance, rate, time, or any combination thereof.

[00121] FIG. 5 illustrates a variator ball 30 according to another embodiment of the invention. The variator ball 30 comprises a main portion 32 and an axle shaft 34. The axle shaft 34 is coupled to the main portion 32 with an interference fit.

[00122] FIG. 6 illustrates the main portion 32. The main portion 32 is a solid spherical body having two flats 36 opposingly formed thereon. The main portion 32 may be formed using a multi-step process. First, a rough sphere is formed from a steel using a forging process. Next, the rough sphere is refined through a grinding process which typically includes passing the rough sphere through rill plates to increase its spherical accuracy. Once the rough sphere has been sufficiently refined through grinding, the resulting sphere is hardened. An outer surface of the sphere is hardened using a carburizing process; however, it is understood that other hardening processes may be used. Next, opposing portions of the sphere is ground to form the flats 36. The grinding process removes the hardened outer surface of the sphere. The flats 36 are parallel to one another and a predetermined amount of the sphere is precisely removed during the grinding process to complete the forming of the main portion 32. Lastly, a perforation 38 is formed through the flats 36 and a center of the main portion 32 using a machining process. Alternately, it is understood that the perforation 38 may be formed through the main portion 32 without the need for the flats 36 to be ground on the main portion 32.

[00123] FIG. 7 illustrates the axle shaft 34. The axle shaft 34 is a solid cylindrical member and includes a first end portion 40, a center portion 42, and a second end portion 44. The axle shaft 34 may be formed using a multi-step process. First, the axle shaft 34 may be roughly formed from a steel using a forging process. Next, the axle shaft 34 may be refined through a machining or a grinding process to increase an accuracy thereof. A shown in FIG. 7, a diameter of the first end portion 40, the center portion 42, and the second end portion 44 are substantially equal to one another; however, it is understood that the first end portion 40, the center portion 42, and the second end portion 44 may have diameters not equal to one another.

[00124] As mentioned hereinabove, to form the variator ball 30, the axle shaft 34 is coupled to the main portion 32 using an interference fit. To couple the axle shaft 34 to the main portion 32 using the interference fit, the main portion 32 is heated prior to coupling. The main portion 32 may be heated in any conventional manner known in the art. Heating the main portion 32 causes the main portion 32 to increase in size, and thus, a diameter of the perforation 38 also increases in size. While the main portion 32 is in the heated state, the main portion 32 is oriented using an alignment device (not shown) that permits the axle shaft 34 to be aligned with the perforation 38, in anticipation of the axle shaft 34 being pressed through the perforation 38. Once the main portion 32 is aligned, the axle shaft 34 is pressed through the perforation 38 in any conventional manner. The alignment device may also facilitate pressing the axle shaft 34 through the perforation 38 a predetermined distance. Once the main portion 32 decreases in temperature, the axle shaft 34 is coupled to the main portion 32. FIG. 8 is a cross-sectional view of the variator ball 30 having the axle shaft 34 coupled to the main portion 32.

[00125] Alternately, it is understood that in addition heating the main portion 32, the axle shaft 34 may be cooled. Cooling the axle shaft 34 causes the axle shaft 34 to decrease in size, and thus, a diameter of the axle shaft 34 also decreases in size. While the axle shaft 34 is in the cooled state, the axle shaft 34 is oriented using an alignment device (not shown) that permits the axle shaft 34 to be aligned with the perforation 38, in anticipation of the axle shaft 34 being pressed through the perforation 38. Further, it is understood that only cooling the axle shaft 34 may permit the axle shaft 34 to be coupled to the main portion 32 with the interference fit.

[00126] Provided herein is a variator ball comprising a main portion, a first axle half shaft and a second axle half shaft manufactured by any one of the methods described herein.

[00127] Provided herein are also method s of manufacturing a variator ball comprising a spherical body, a first axle half shaft and a second axle half shaft, the method comprising: attaching the first axle half shaft to the spherical body of the variator ball by friction welding or projection welding, and attaching the second axle half shaft to the spherical body of the variator ball by friction welding or projection welding.

[00128] In some embodiments, the methods described herein further comprise hardening an outer surface of the variator ball. In some embodiments, the hardening step comprises carburizing the outer surface of the variator ball.

[00129] In some embodiments, the methods described herein comprise sorting or manufacturing the variator ball to be: within a 0.001 inch range around a target dimension of said ball, within a 0.0005 inch range around a target dimension of said ball, or within a 0.0001 inch range around a target dimension of said ball. In some embodiments, the target dimension of said ball is a diameter of said ball.

[00130] In some embodiments, the methods described herein comprise sorting or manufacturing the first axle half shaft to be: within a 0.001 inch range around a target dimension of said first axle half shaft, within a 0.0005 inch range around a target dimension of said first axle half shaft, or within a 0.0001 inch range around a target dimension of said first axle half shaft. In some embodiments, the target dimension of said first axle half shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said first axle half shaft.

[00131] In some embodiments, methods described herein comprise sorting or manufacturing the second axle half shaft to be: within a 0.001 inch range around a target dimension of said second axle half shaft, within a 0.0005 inch range around a target dimension of said second axle half shaft, or within a 0.0001 inch range around a target dimension of said second axle half shaft. In some embodiments, the target dimension of said second axle half shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said second axle half shaft.

[00132] In some embodiments, the methods described herein comprise sorting or manufacturing the axle shaft to be: within a 0.001 inch range around a target dimension of said axle shaft, within a 0.0005 inch range around a target dimension of said axle shaft, or within a 0.0001 inch range around a target dimension of said axle shaft. In some embodiments, the target dimension of said axle shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said axle shaft.

[00133] Provided herein is a variator ball comprising a main portion, a first axle half shaft and a second axle half shaft manufactured by any one of the methods described herein. Provided herein is a variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein.

[00134] Provided herein is a variable transmission comprising the variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein. In some embodiments, the variable transmission comprises a traction fluid.

[00135] Provided herein is a vehicle driveline comprising an engine, a variable transmission comprising the variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein, and a vehicle output.

[00136] Provided herein is a vehicle comprising the variable transmission comprising a variator ball formed by any of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein.

[00137] Provided herein is a manufacturing apparatus that implements any of the methods described herein in full or in part, or according to methods obvious to one of skill in the art upon reading the disclosure herein.

[00138] Provided herein is a variator ball comprising a spherical ball, a first axle half shaft and a second axle half shaft manufactured by any one of the methods described herein or obvious to one of skill in the art upon reading the disclosure herein.

[00139] In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiments. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.

[00140] It is to be understood that the invention may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined herein. Hence, specific dimensions, directions or other physical characteristics relating to the embodiments disclosed are not to be considered as limiting, unless expressly stated otherwise.

[00141] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

CLAIMS

WHAT IS CLAIMED IS:

1. A method of manufacturing a variator ball comprising a main portion, a first axle half shaft and a second axle half shaft, the method comprising:

- creating the main portion of the variator ball by

  forming a first flat portion on a solid spherical body, and

  forming a second flat portion on the solid spherical body that is parallel to the first flat portion;

- attaching the first axle half shaft to the first flat portion; and
- attaching the second axle half shaft to the second flat portion.

2. The method of claim 1, wherein the solid spherical body is formed by forging a rough sphere.

3. The method of claim 2, wherein the rough sphere comprises steel.

4. The method of claim 2, comprising improving the spherical accuracy of the rough sphere.

5. The method of claim 4, wherein improving the spherical accuracy of the rough sphere comprises passing the rough sphere through rill plates.

6. The method of claim 4, wherein improving the spherical accuracy of the rough sphere comprises grinding the rough sphere.

7. The method of claim 1, comprising hardening an outer surface of the solid spherical body.

8. The method of claim 7, wherein the hardening step comprises carburizing the outer surface of the solid spherical body.

9. The method of claim 7, wherein forming the first flat portion comprises removing the hardened outer surface of the solid spherical body such that a non-hardened portion of the solid spherical body is exposed and makes up the center of the first flat portion.

10. The method of claim 1, wherein forming the first flat portion and forming the second flat portion comprises grinding opposing portions of the solid spherical body.

11. The method of claim 1, wherein a first body axis passing through the center of the solid spherical body is orthogonal to the first flat portion.

12. The method of claim 11, wherein a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion, and aligns with the first body axis.

13. The method of claim 11, wherein at least one of the first axle half shaft and the second axle half shaft form an axle axis that aligns with the first body axis.

14. The method of claim 1, wherein a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion.

15. The method of claim 1, wherein forming the first flat portion and forming the second flat portion removes a predetermined amount of the spherical body.

16. The method of claim 1, wherein attaching the first axle half shaft to the first flat portion comprises projection welding the first axle half shaft to the first flat portion.

17. The method of claim 16, wherein the first axle half shaft comprises a first axle portion and a first projection.

18. The method of claim 17, wherein the first axle half shaft is manufactured by forging a roughly formed first axle half shaft and machining or grinding the roughly formed first axle half shaft to increase the accuracy of the first axle portion and/or to refine the shape of the first projection.

19. The method of claim 17, wherein the first axle portion is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross section.

20. The method of claim 17, wherein the first projection has a predetermined cross-sectional area and shape that facilitates forming a projection weld between the first axle half shaft and the first flat portion.

21. The method of claim 17, wherein the first projection has a cross-sectional area and shape equal to a cross-sectional area and shape of the first axle portion.

22. The method of claim 17, wherein projection welding first axle half shaft to the first flat portion comprises

- disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith,
- disposing the first projection against the first flat portion,
- aligning the main portion with the first axle half shaft,
- contacting a second welding terminal to the first axle portion which, thereby, is in electrical communication therewith,
- applying force to the first axle portion against the first flat portion, and
- passing an electrical current from the second welding terminal to the first welding terminal through the first axle half shaft and the main portion, thereby causing the first projection to increase to a welding temperature.

23. The method of claim 17, wherein projection welding first axle half shaft to the first flat portion comprises

- disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith,
- disposing the first projection against the first flat portion,
- aligning the main portion with the first axle half shaft,
- contacting a second welding terminal to the first axle portion, which, thereby, is in electrical communication therewith,
- applying force to the first axle portion against the first flat portion, and
- passing an electrical current from the first welding terminal to the second welding terminal through the first axle half shaft and the main portion, thereby causing the first projection to increase to a welding temperature.

24. The method of claim 22 or 23, wherein the electrical current increases the first flat portion to the welding temperature.

25. The method of claim 22 or 23, wherein the force applied by the second welding terminal causes the first projection to deform and spread between the first flat portion and the first axle portion to form a projection weld.

26. The method of claim 22 or 23, further comprising stopping the electrical current after moving the first axle half shaft a predetermined distance toward the main portion.

27. The method of claim 22 or 23, further comprising stopping the electrical current after applying a predetermined amount of the force for a predetermined time.

28. The method of claim 22 or 23, wherein aligning the main portion with the first axle half shaft uses an alignment tool.

29. The method of claim 1, wherein attaching the second axle half shaft to the second flat portion comprises projection welding the second axle half shaft to the second flat portion.

30. The method of claim 29, wherein the second axle half shaft comprises a second axle portion and a second projection.

31. The method of claim 30, wherein the second axle half is manufactured by forging a roughly formed second axle half and machining or grinding the roughly formed second axle half to increase the accuracy of the second axle portion and/or to refine the shape of the second projection.

32. The method of claim 30, wherein the second axle portion is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross-section.

33. The method of claim 30, wherein the second projection has a predetermined cross-sectional area and shape that facilitates forming a projection weld between the second axle half shaft and the second flat portion.

34. The method of claim 30, wherein the second projection has a cross-sectional area and shape equal to a cross-sectional area and shape of the second axle portion.

35. The method of claim 30, wherein projection welding second axle half shaft to the second flat portion comprises

- disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith,
- disposing the second projection against the second flat portion,
- aligning the main portion with the second axle half shaft,
- contacting a second welding terminal to the second axle portion, which, thereby, is in electrical communication therewith,
- applying force to the second axle portion against the first flat portion, and
- passing an electrical current from the second welding terminal to the first welding terminal through the second axle half shaft and the main portion, thereby causing the second projection to increase to a welding temperature.

36. The method of claim 30, wherein projection welding second axle half shaft to the second flat portion comprises

- disposing the main portion against a first welding terminal which, thereby, is in electrical communication therewith,
- disposing the second projection against the second flat portion,
- aligning the main portion with the second axle half shaft,
- contacting a second welding terminal to the second axle portion, which, thereby, is in electrical communication therewith,
- applying force to the second axle portion against the second flat portion, and
- passing an electrical current from the first welding terminal to the second welding terminal through the second axle half shaft and the main portion, thereby causing the second projection to increase to a welding temperature.

37. The method of claim 35 or 36, wherein the electrical current increases the second flat portion to the welding temperature.

38. The method of claim 35 or 36, wherein the force applied by the second welding terminal causes the second projection to deform and spread between the second flat portion and the second axle portion to form a projection weld.

39. The method of claim 35 or 36, further comprising stopping the electrical current after moving the second axle half shaft a predetermined distance toward the main portion.

40. The method of claim 35 or 36, further comprising stopping the electrical current after applying a predetermined amount of the force for a predetermined time.

41. The method of claim 35 or 36, wherein aligning the main portion with the second axle half shaft uses an alignment tool.

42. The method of claim 1, wherein attaching the first axle half shaft to the first flat portion comprises friction welding the first axle half shaft to the first flat portion.

43. The method of claim 42, wherein friction welding first axle half shaft to the first flat portion comprises

- holding the main portion stationary,
- rotating the first axle half shaft,
- pressing a first portion of the rotating first axle half shaft against first flat portion, thereby generating heat from the friction between the first portion of the first axle half shaft and the first flat portion that heats the first portion and the first flat portion to a welding temperature, and
- stopping the rotation of the first axle half shaft once the welding temperature is reached.

44. The method of claim 42, wherein friction welding first axle half shaft to the first flat portion comprises

- holding the first axle half shaft stationary,

- rotating the main portion,
- pressing a first portion of the first axle half shaft against first flat portion, thereby generating heat from the friction between the first portion of the first axle half shaft and the first flat portion that heats the first portion and the first flat portion to a welding temperature, and
- stopping the rotation of the main portion once the welding temperature is reached.

45. The method of claim 1, wherein attaching the second axle half shaft to the second flat portion comprises friction welding the second axle half shaft to the second flat portion.

46. The method of claim 45, wherein friction welding second axle half shaft to the second flat portion comprises

- holding the main portion stationary,
- rotating the second axle half shaft,
- pressing a second portion of the rotating second axle half shaft against second flat portion, thereby generating heat from the friction between the second portion of the second axle half shaft and the second flat portion that heats the second portion and the second flat portion to a welding temperature, and
- stopping the rotation of the second axle half shaft once the welding temperature is reached.

47. The method of claim 45, wherein friction welding second axle half shaft to the second flat portion comprises

- holding the second axle half shaft stationary,
- rotating the main portion,
- pressing a second portion of the second axle half shaft against second flat portion, thereby generating heat from the friction between the second portion of the second axle half shaft and the second flat portion that heats the second portion and the second flat portion to a welding temperature, and
- stopping the rotation of the main portion once the welding temperature is reached.

48. The method of claim 1, comprising simultaneously attaching the first axle half shaft to the first flat portion and attaching the second axle half shaft to the second flat portion using friction welding.

49. The method of claim 1, comprising sequentially attaching the first axle half shaft to the first flat portion using friction welding and then attaching the second axle half shaft to the second flat portion using friction welding.

50. The method of claim 1, wherein attaching the axle half shaft to the second flat portion comprises friction welding the second axle half shaft to the second flat portion.

51. A method of manufacturing a variator ball comprising a main portion and an axle shaft having a first end portion, a second end portion and a center portion, the method comprising:

- creating a perforation through the center of a solid spherical body to form the main portion of the variator ball; and
- coupling the axle shaft using an interference fit process comprising

  heating the main portion sufficiently to increase the size of the perforation in the main portion,

  aligning the axle shaft with the perforation, or aligning the perforation with the axle shaft, pressing the axle shaft through the perforation, and

  decreasing the temperature the main portion, or allowing said main portion to decrease in temperature.

52. A method of manufacturing a variator ball comprising a main portion and an axle shaft having a first end portion, a second end portion and a center portion, the method comprising:

- creating a perforation through the center of a solid spherical body to form the main portion of the variator ball; and
- coupling the axle shaft using an interference fit process comprising

  cooling the axle shaft sufficiently to decrease the size of a diameter of the axle shaft,

  aligning the axle shaft with the perforation, or aligning the perforation with the axle shaft, pressing the axle shaft through the perforation, and

  increasing the temperature the axle shaft, or allowing said axle shaft to increase in temperature.

53. The method of claim 51 further comprising cooling the axle shaft sufficiently to decrease the size of a diameter of the axle shaft prior to pressing the axle shaft into the perforation, and subsequently increasing the temperature the axle shaft, or allowing said axle shaft to increase in temperature.

54. The method of claim 51, 52, or 53, further comprising:

- forming a first flat portion on the solid spherical body; and
- forming a second flat portion on the solid spherical body that is parallel to the first flat portion,

wherein the perforation is created through the first flat portion and the second flat portion.

55. The method of claim 51 or 52, wherein the solid spherical body is formed by forging a rough sphere.

56. The method of claim 55, wherein the rough sphere comprises steel.

57. The method of claim 55, comprising improving the spherical accuracy of the rough sphere.

58. The method of claim 57, wherein improving the spherical accuracy of the rough sphere comprises passing the rough sphere through rill plates.

59. The method of claim 57, wherein improving the spherical accuracy of the rough sphere comprises grinding the rough sphere.

60. The method of claim 51 or 52, comprising hardening an outer surface of the solid spherical body.

61. The method of claim 60, wherein the hardening step comprises carburizing the outer surface of the solid spherical body.

62. The method of claim 53, comprising hardening an outer surface of the solid spherical body wherein forming the first flat portion comprises removing the hardened outer surface of the solid spherical body such that a non-hardened portion of the solid spherical body is exposed and makes up the center of the first flat portion.

63. The method of claim 53, wherein forming the first flat portion and forming the second flat portion comprises grinding opposing portions of the solid spherical body.

64. The method of claim 53, wherein a first body axis passing through the center of the solid spherical body is orthogonal to the first flat portion.

65. The method of claim 64, wherein a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion, and aligns with the first body axis.

66. The method of claim 64, wherein the axle shaft forms an axle axis that aligns with the first body axis.

67. The method of claim 53, wherein a second body axis passing through the center of the solid spherical body is orthogonal to the second flat portion.

68. The method of claim 53, wherein forming the first flat portion and forming the second flat portion removes a predetermined amount of the spherical body.

69. The method of claim 51 or 52, wherein the axle shaft is solid.

70. The method of claim 51 or 52, wherein the axle shaft is a solid cylindrical member.

71. The method of claim 51 or 52, wherein the axle shaft comprises a shape that is generally cylindrical, generally columnal having a polygonal cross-section, or generally columnal having an oval cross section.

72. The method of claim 70 or 71, wherein the perforation shape aligns with the shape of the axle shaft.

73. The method of claim 51 or 52, wherein the axle shaft is forging from steel.

74. The method of claim 73, comprising refining the axle shaft shape by grinding or machining the axle shaft.

75. The method of claim 51 or 52, wherein at least two of a first end portion diameter of the first end portion, a center portion diameter of the center portion, and a second end portion diameter of the second end portion are substantially equal to one another.

76. The method of claim 75, wherein all three of the first end portion diameter, the center portion diameter, and the second end portion diameter are substantially equal to one another.

77. The method of claim 51 or 52, wherein at least one of a first end portion shape of the first end portion, a center portion shape of the center portion, and a second end portion shape of the second end

portion is different than another of the first end portion shape, the center portion shape, and the second end portion shape.

78. The method of claim 51 or 52, comprising pressing the axle shaft through the perforation a predetermined distance, or using a predetermined rate for a predetermined time.

79. The method of claim 78, comprising using an alignment device to press the axle shaft through the perforation, wherein the alignment device allows for control of the distance, rate, time, or any combination thereof.

80. A variator ball comprising a main portion, a first axle half shaft and a second axle half shaft manufactured by any one of the methods of claims 1-79.

81. A method of manufacturing a variator ball comprising a spherical body, a first axle half shaft and a second axle half shaft, the method comprising:

- attaching the first axle half shaft to the spherical body of the variator ball by friction welding or projection welding; and
- attaching the second axle half shaft to the spherical body of the variator ball by friction welding or projection welding.

82. The method of claim 1 or 81, further comprising hardening an outer surface of the variator ball.

83. The method of claim 82, wherein the hardening step comprises carburizing the outer surface of the variator ball.

84. The method of claim 1, 51, 52, or 81 comprising sorting or manufacturing the variator ball to be: within a 0.001 inch range around a target dimension of said ball, within a 0.0005 inch range around a target dimension of said ball, or within a 0.0001 inch range around a target dimension of said ball.

85. The method of claim 84, wherein the target dimension of said ball is a diameter of said ball.

86. The method of claim 1 or 81, comprising sorting or manufacturing the first axle half shaft to be: within a 0.001 inch range around a target dimension of said first axle half shaft, within a 0.0005 inch range around a target dimension of said first axle half shaft, or within a 0.0001 inch range around a target dimension of said first axle half shaft.

87. The method of claim 86, wherein the target dimension of said first axle half shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said first axle half shaft.

88. The method of claim 1 or 81, comprising sorting or manufacturing the second axle half shaft to be: within a 0.001 inch range around a target dimension of said second axle half shaft, within a 0.0005 inch range around a target dimension of said second axle half shaft, or within a 0.0001 inch range around a target dimension of said second axle half shaft.

89. The method of 88, wherein the target dimension of said second axle half shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said second axle half shaft.

90. The method of claim 51 or 52, comprising sorting or manufacturing the axle shaft to be: within a 0.001 inch range around a target dimension of said axle shaft, within a 0.0005 inch range around a target dimension of said axle shaft, or within a 0.0001 inch range around a target dimension of said axle shaft.

91. The method of 90 wherein the target dimension of said axle shaft is a cross-sectional diameter, a projection maximum diameter, a projection minimum diameter, a projection length, or another length of said axle shaft.

92. A variator ball formed by any of the methods of claims 1-79 or 81-91.

93. A variable transmission comprising the variator ball of claim 80 or 92.

94. The variable transmission of claim 93, comprising a traction fluid.

95. A vehicle driveline comprising an engine, a variable transmission comprising the variator ball of claim 93, and a vehicle output.

96. A vehicle comprising the variable transmission of claim 93.

97. A manufacturing apparatus that implements any of the methods, in full or in part, of claims 1-79 or 81-91.

98. A variator ball comprising a spherical ball, a first axle half shaft and a second axle half shaft manufactured by any one of the methods of claims 81-91.

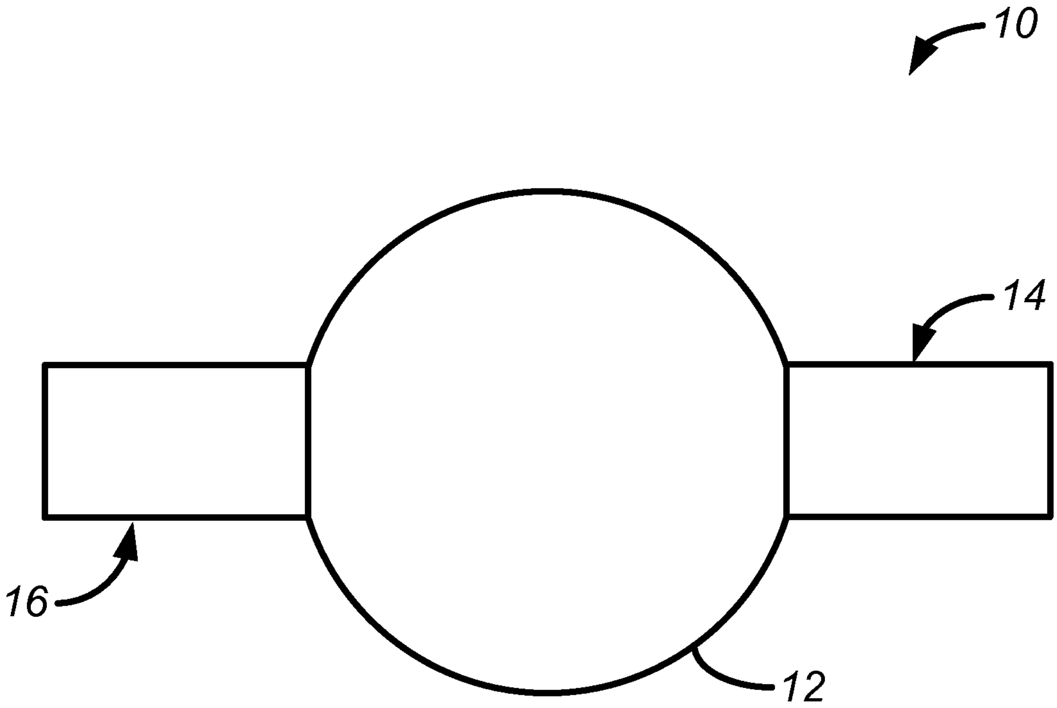

FIG. 1

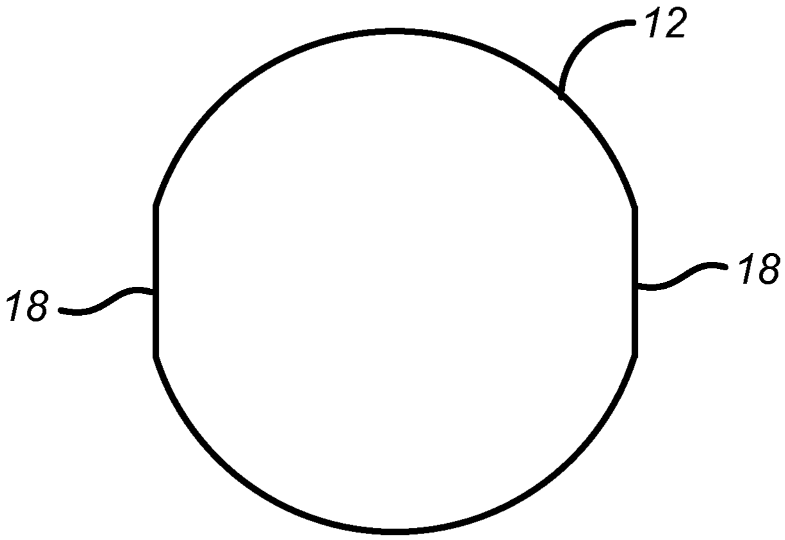

FIG. 2

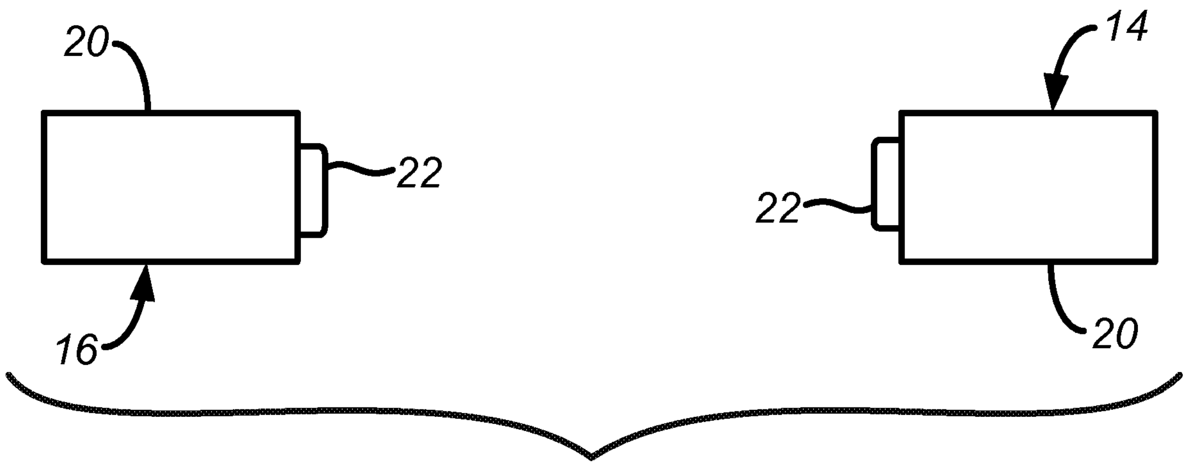

FIG. 3

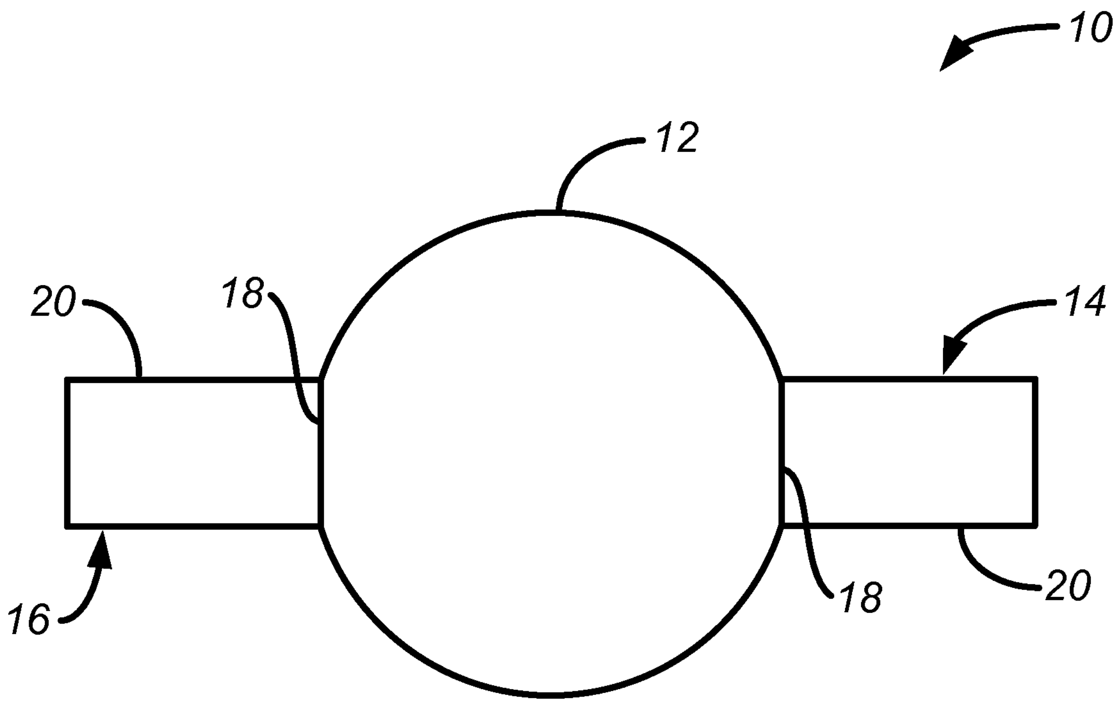

FIG. 4

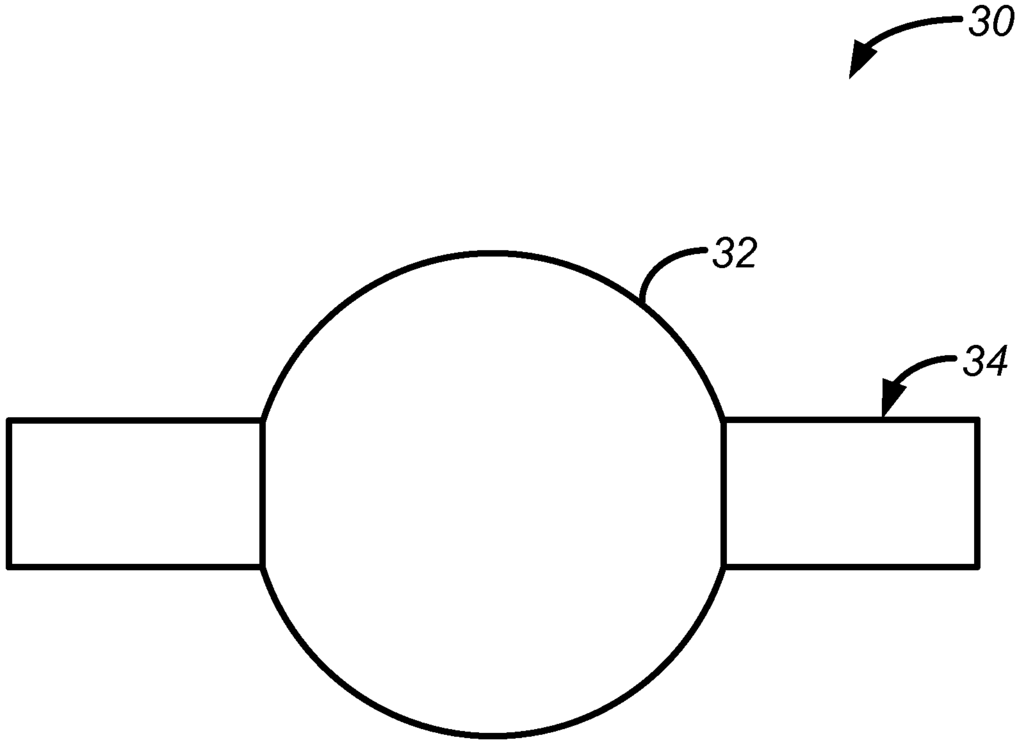

FIG. 5

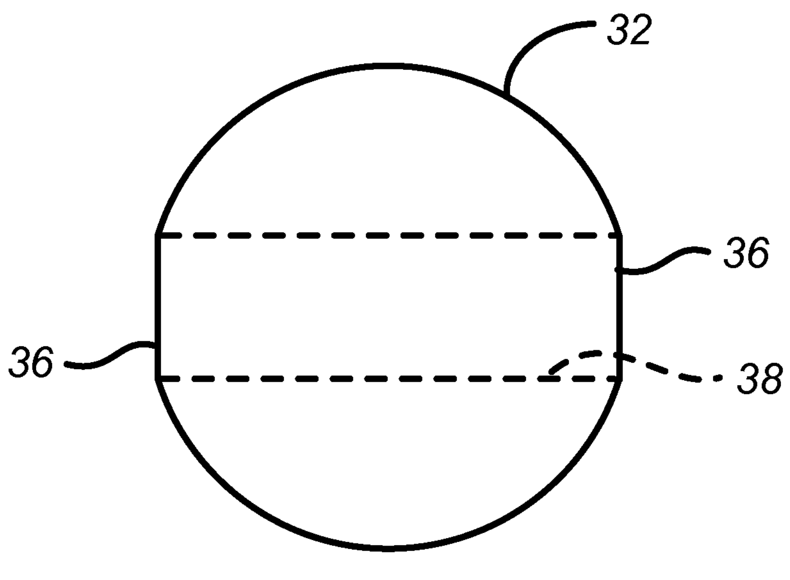

FIG. 6

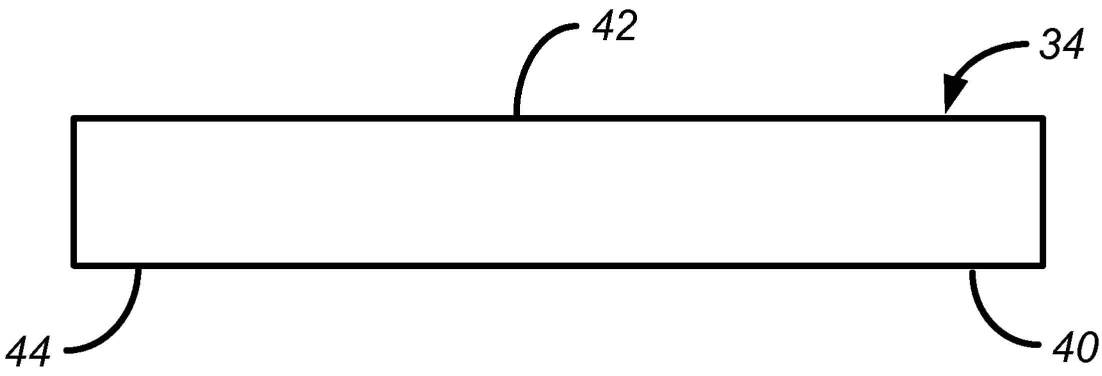

FIG. 7

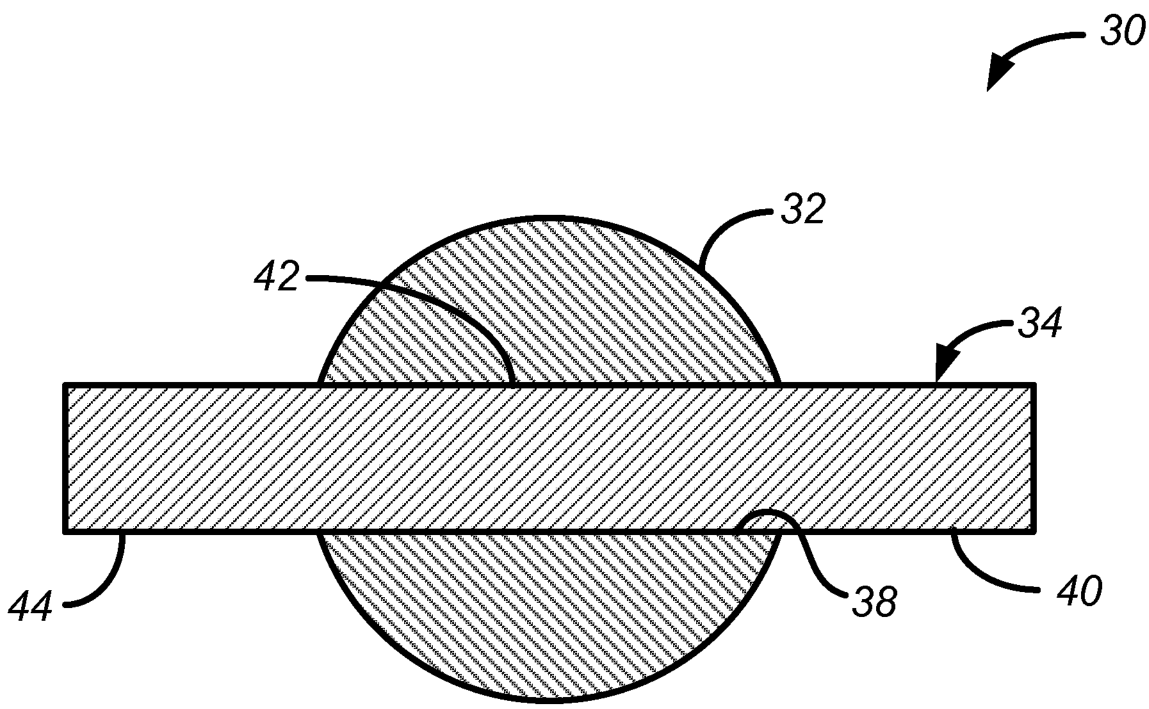

FIG. 8