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### Combined shock absorber and gas spring

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#### Abstract

A combination gas spring and shock absorber apparatus includes a vented gas spring housing and a vented shock absorber housing slidably mounted within the gas spring housing. A shock absorber piston is concentrically mounted within a gas spring piston. A base housing is slidably mounted in the gas spring housing. A shaft extends through the base housing and into the shock absorber housing. The shock absorber piston is mounted in the shock absorber housing on the free end of the shaft. The gas spring piston is mounted in the gas spring housing on the distal end of the base housing. The shock absorber piston is fluidically sealed and slides within the shock absorber housing. The gas spring piston is fluidically sealed and slides along the gas spring housing and the shock absorber housing. The base housing telescopically translates relative to the gas spring housing.

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## **Background/Summary**

### TECHNICAL FIELD

(1) This invention relates to the field of vehicle suspension and control, and in particular to a vehicle component having a combined gas spring and shock absorber.

### SUMMARY

(2) In one aspect of the present disclosure, the suspension assembly of each wheel is independently adjustable and consists of an adjustable suspension gas spring having at least two chambers, an inlet/outlet valve is provided for each chamber, whereby the pressure in either or both of the chambers may be individually and independently adjusted by a controlled set of valves. In one embodiment, by way of example, the valves cooperate with an on-board processor.

Advantageously, such a dual-chamber adjustable suspension gas spring is controlled by the processor in response to sensor inputs or user-selected pre-set operating modes which, for example in the case of wheeled vehicles, enable both ride height adjustment of each individual wheel, as well as providing for forced (as opposed to passive) extension or retraction of the spring and/or adjusting the stiffness of the adjustable suspension gas spring so as to adjust the spring rate. A shock absorber component is mounted within the gas spring, and cooperates with the gas spring as a component which is integral to the gas spring.

(3) Although the adjustable, dual-chamber suspension gas spring and the shock absorber are generally described herein as using air for the operating gas, it will be appreciated by a person skilled in the art that the present disclosure is not so limited and that other gases or fluids may be utilized as the operating gas or fluid to independently change the pressure in the chambers of the adjustable suspension gas spring or shock absorber. For example, compressed CO<sub>2</sub> or other suitable compressed gases, or as another example, hydraulic fluids used in conjunction with air or another compressible gas or compressible fluid to change the pressure of the compressible gas or fluid, may also be employed.

### BACKGROUND

(4) An active vehicle suspension is described in published patent application WO2018141049A1 for the invention of Gebhard Wager wherein adjustable air springs are described. FIG. 1 in that published application describes an active suspension system **10** which includes a valve assembly **12**, such as a valve block, operatively connected to a fluid source **14** and an electronic controller **16**. The valve assembly **12** may comprise a plurality of bidirectional valves, wherein each bidirectional valve is connected to a fluid line leading to either the upper chamber or the lower chamber of an adjustable suspension air spring.

(5) As shown in FIG. 1 in that prior art publication, and reproduced herein as FIG. 1, adjustable suspension gas springs **20** and **22** are operatively coupled to the front left and right wheel assemblies respectively, and adjustable suspension gas springs **30** and **32** are operatively coupled to

the rear left and right wheel assemblies respectively of a four-wheeled off-road vehicle **1**. The adjustable suspension springs **20**, **22**, **30**, and **32**, may each comprise of a cylinder **24**, a piston **26** and a piston shaft **27** having coupling **28** for coupling to the respective wheel assembly.

(6) Each adjustable suspension spring is divided into two chambers. For example, the front left adjustable suspension spring **20** is divided into an upper chamber **20a** and a lower chamber **20b**. The upper and lower chambers **20a**, **20b**, are separated by the piston **26**. Piston shaft **27** extends through the lower chamber **20b** and is adjacent wheel assembly coupling **28**. Thus, when a wheel assembly coupled to an adjustable suspension spring encounters, for example, a rock, log or other obstacle on the terrain over which the vehicle is travelling, or during travel detects body roll, the approximately vertical force of the force vector experienced by the wheel is transmitted through the coupling **28** and shaft **27** to slide the piston **26**, thereby increasing the pressure in the upper chamber (**20a**, for example) and decreasing the pressure in the lower chamber (**20b**, for example), presuming that the operating fluids in the upper and lower chambers are compressible.

(7) Referring now to the electronically controlled embodiment, each of the upper and lower chambers of each of the adjustable suspension springs **20**, **22**, **30**, **32** are provided with a position sensor **33** for monitoring the ride height of each individual wheel, specifically monitoring when each individual wheel is adjusted to maximum and minimum ride heights. The position sensors **33** are in electronic communication with electronic controller **16**. Control to adjust suspension springs **20**, **22**, **30**, **32** may be electronic or automatic, or may also be manual.

(8) Similarly, adjustable suspension spring **22** is divided into upper and lower chambers **22a**, **22b**; adjustable suspension spring **30** is divided into upper and lower chambers **30a**, **30b**; and adjustable suspension spring **32** is divided into upper and lower chambers **32a**, **32b**. Each of the upper and lower chambers **20a**, **20b** of the adjustable suspension spring **20** are provided with a port **25** fluidly coupled to a fluid line **23**, and each fluid line **23** is attached at the other end to a valve **21** mounted to the valve assembly **12**. Similarly, the upper and lower chambers of each of the other adjustable suspension springs **22**, **30**, **32**, each are provided with a port **25** coupled to a fluid line **23**, whereby the opposite end of the fluid line **23** is coupled to a valve **21** mounted to the valve assembly **12**. Furthermore, each of the upper and lower chambers of each of the adjustable suspension springs **20**, **22**, **30**, **32**, are provided with a pressure sensor **29** for monitoring the pressure of each chamber. The pressure sensors **29** are in electronic communication with electronic controller **16**.

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## Description

### BRIEF DESCRIPTION OF DRAWINGS

- (1) FIG. 1 depicts an active vehicle suspension system in accordance with the prior art.
- (2) FIG. 2 depicts a cross-sectional view of a combined gas spring/shock absorber in accordance with an embodiment of the present invention.
- (3) FIG. 3 depicts a cross-sectional view of the combined gas spring/shock absorber with a built-in compressor function in accordance with an embodiment of the present invention.
- (4) FIG. 4 depicts a cross-sectional view of the combined gas spring/shock absorber in a single housing operation in accordance with an embodiment of the present invention.
- (5) FIG. 5 depicts cross-sectional view of the embodiment of FIG. 4 adapted to be mounted on the frame of a vehicle in accordance with an embodiment of the present invention.

### DETAILED DESCRIPTION

- (6) In the present invention, each adjustable suspension spring combines a gas spring with an internally mounted shock absorber. Briefly put, a shock absorber is a mechanical or hydraulic device which absorbs and dampens shock impulses, surface road conditions of the terrain on which vehicles with shock absorbers drive. Most shock absorbers are a form of dashpot.
- (7) Many pneumatic and hydraulic shock absorbers are conventionally used in conjunction with

springs and/or cushions. The springs may be helical coil springs, and the shock absorber, being usually cylindrical, may fit inside the spring. Those forms of shock absorbers are sometimes referred to as “coil-over shocks”.

(8) The combined gas spring/shock absorber **100** in the embodiment of the present invention depicted in FIG. 2 includes a gas spring modified so that a mono-tube shock absorber is slidably mounted internally within the gas spring.

(9) Thus as seen in FIG. 2, shock absorber housing **102** translates in direction A along longitudinal and centroidal axis B relative to gas spring housing **20'** upon a force acting in direction C on, for example, a lower end of the shock absorber housing **102**.

(10) Within shock absorber housing **102**, a base housing **104** is slidably journaled in annular seals **106a** in the lower, ring-shaped base **106** of gas spring housing **20'**. It will be appreciated that base housing **104** replaces the function of piston shaft **27** in the gas spring embodiment of FIG. 1. Thus the upper end of base housing **104** is mounted to piston **26**; being a modified piston **26**. As with piston **26**, piston **26'** floats slidably along the interior of the cylindrical wall **108** of gas spring housing **20'**. Piston **26'** moves in direction D within cylinder **108**.

(11) Shock absorber shaft **110** lies along axis B and moves relative to both gas spring housing **20'** and base housing **104**. Again, base housing **104** also moves relative to gas spring housing **20'**. A sealed lower disc or ring or piston **112** slidably anchors the lower end of shaft **110** within base housing **104**. Seals **112a** fluidically seal the upper chamber **114** within base housing **104** of shock absorber housing **102** from the lower chamber **116** within base housing **104**. Lower piston **112** moves in direction E within base housing **104**. In this embodiment chambers **114** and **116** are filled with oil. In other embodiments the chambers may be filled with gas such as air. As will be appreciated by one skilled in the art, reference to upper and lower is to assist in understanding FIG. 2, and not intended to be limiting as references herein to upper/lower or up/down or top/bottom may be reversed or oriented differently, for example horizontally in a side-by-side configuration, in other embodiments.

(12) A bypass line **118** extends through lower piston **112** via aperture **118a** and along shaft **110** for the passing of the oil between chambers **114** and **116**. Bypass valve **120** cooperates with bypass line **118**. The bypass valve **120** is electronically controlled and may be opened to soften the shock absorber housing **102** when the vehicle is travelling for example, on rocky terrain. Oil passing from chamber **116** then line **118** is returned into the hollow chamber **110a** within and along shaft **110** to exit into chamber **114** via bypass port **110b**. Oil may also flow oppositely to travel from chamber **114** to chamber **116**, for example, when upward movement of lower piston **112** compresses the oil in chamber **114**. Oil may also follow between chamber **114** and **116** in direction E through threaded apertures **118b** in piston **112** in which are seated flow adjustment screws **122a**. The oil flow rate through apertures **118b** is varied by adjusting screws **122a**.

(13) Optionally a floating piston **124**, also seen in FIG. 2, slidably mounted and sealed by seals **124a** within the lower-most end of base housing **104** partitions chamber **116** from bump stop air chamber **126**. Stops **128**, mounted or formed on the inside wall of base housing **104**, limit the upper travel of floating piston **124**. The pressurized gas within air chamber **126** provides the resilient air bump against which floating piston **124** may engage at the lower end of its travel and provides cushioning for jarring harsh bumps. Air to pressure chamber **126** is provided from a pressurized air source (not shown) via port **126a**.

(14) Gas spring housing **20'** is mounted over the upper end of shock absorber housing **102** so as to rest the upper end of shock absorber housing **102**, and in particular piston **26'** within cylindrical wall **108**, between gas spring air chambers **20a'** and **20b'**. Piston **26'** is sealed against wall **108** by seals **26a'** and against chamber **110a** by inner seal **26c'**. The operating gas (e.g. air) is supplied to, or extracted from, air chambers **20a'**, **20b'**, via the air conduits **23a** and **23b** respectively. Air conduits **23a**, **23b** lead to a pressurized gas source (not shown). Chambers **20a'** and **20b'** may thus be selectively and independently pressurized or de-pressurized to create a pressure differential

between the chambers **20a'**, **20b'** to urge piston **26'** in the desired vertical direction and/or to modify the gas spring rate. The vertical travel of piston **26'** along cylinder **108** is bounded at the bottom end by base **106** and at the upper end by either the top of cylinder **108** or, optionally, by a floating piston **130** providing an air bump at the upper end of base housing **104**, which slides along and within, in sealed engagement with, the inner surface of the wall of cylinder **108**, sealed by seal **130a**. Downward travel of piston **130** is limited by stop **132**. Piston **130** defines a gas chamber **134** between piston **130** and the closed upper end **108a** of cylinder **108**. Pressurized gas (e.g. air) is supplied to gas chamber **134** via port **134a** from a pressurized gas source (not shown). The pressurized gas within gas chamber **134** provides the resilient air bump against which piston **26'** may engage at the upper end of its travel.

(15) Both piston **26'** and piston **130** may have an annular perimeter channel **26b'** and **130b** respectively formed in their upper surfaces to accommodate gas passing into or out of their respective chambers **20a'**, **134** from their respective gas ports **26**, **134a**.

(16) Advantageously, the combined gas spring/shock absorber **100** is infinitely adjustable in the field. The gas spring/shock absorber **100** is adjustable in both up and down vertical directions and may adjust spring rate without ride height adjustment. Furthermore, the gas spring/shock absorber **100** may provide an anti-sway function to remove body roll when turning by adjusting the ride height of the front and rear inside turning wheels of the vehicle as described later in respect of the embodiment of FIG. 4, the gas spring may be over-driven to give instantaneous plush or softer spring rate suspension to one wheel when, for example, encountering an obstacle such as a log or boulder.

(17) Again, reference herein to up/down, top/bottom, upper/lower is not intended to be limiting as other orientations will also work, for example if the orientation is altered by 90 or 180 degrees so that up/down becomes side-to-side or down/up respectively.

(18) In some embodiments of the present disclosure, the combined gas spring/shock absorber **100** includes a built in compressor function, as shown in FIG. 3, so as to further assist with ride comfort, handling, and vehicle control, functioning analogous to a strut, and so as to provide a more self-contained unit. In this embodiment of the present disclosure, the shock absorber shaft **110** is divided into an upper chamber **140a** and lower chamber **140b** whereby the upper chamber **140a** and lower chamber **140b** are separated by a piston **142**. An inlet valve **144a** and outlet valve **146a** are provided for the upper chamber **140a** whereby air enters the chamber **140a** through the inlet valve **144a** and compressed air flows out from the chamber **140a** through the outlet valve **146a**. In addition, an inlet valve **144b** and outlet valve **146b** are provided for the bypass line **118**, which extends along the shaft **110**, through lower chamber **140b**. Air flows from the inlet valve **144b**, through the bypass line **118**, to the lower chamber **140b** via apertures **148a**, **148b** in the bypass line **118**. Compressed air may flow from the lower chamber **140b** to the outlet valve **146b** via apertures **148a**, **148b** in the bypass line **118**. The outlet valves **146a**, **146b** are connected to storage tanks, for storage of the compressed air, or to other chambers (eg. other cylinders), or to atmosphere. Storage tanks are not illustrated in the Figures for sake of clarity.

(19) Each of the upper and lower chambers **140a**, **140b**, is provided with a pressure sensor (not shown) for monitoring the pressure of each chamber and controlling the flow of air into the upper and lower chambers **140a**, **140b** of the shock absorber shaft **110** through the inlet valves **144a**, **144b**, and the flow of compressed air out of the chambers **140a**, **140b** through the outlet valves **146a**, **146b**. The pressure sensors **29** are in electronic communication with electronic controller **16**; however, wires between the pressure sensors **29** and the electronic controller **16** are not illustrated in the Figures for the sake of clarity. In other embodiments of the present disclosure, the electronic communication between the electronic controller **16** and the pressure sensors **29** may also be accomplished wirelessly.

(20) In the embodiment of FIG. 4, a combined gas spring and shock absorber **400**, in a single housing operation, provides controllable, low pressure, all-in-one suspension for vehicles including

wheeled vehicles, tracked vehicles including snowmobiles, etc.

(21) Characteristics of a combined gas spring/shock absorber **400** may include low pressure compression in the gas spring making it adjustable during use, a low pressure built-in shock absorber using gas or fluid. The gas option for the gas spring uses no oil, and when the gas is air uses atmospheric air for control and cooling, and provides complete compression and rebound control. Gas spring/shock absorber **400** has multiple chambers, allowing it to have multiple compressor options, reverse itself, over or under drive itself by augmenting pressures or counteracting them, influence or transfer pressure to other springs in the vehicle system. The system provides for substantially completely, exponentially tuning spring rate, travel, sway, pitch, roll, angles, speed, and comfort in both the shock absorber and gas, and may be used as a strut or steering strut. Gas spring/shock absorber **400** is advantageously light, compact, and completely self-contained, providing shock, sway bar, spring, height, cornering and tilt control. It is versatile, scaleable and simple.

(22) As seen in the cross-sectional view of FIG. 4, chamber A' supports the vehicle weight and provides the spring rate. Chambers B' and D' provide the reverse spring force, for example to raise the corresponding wheel or track or to change the spring rate. Chambers B' and D' also may help dampen oscillations; that is, act as a shock absorber, by releasing air to the atmosphere, or drawing air in from the atmosphere through valves **402** and **404** respectively each time the gas spring (A,' C' over B', D') compresses or rebounds. The air flow velocity through the valves **404** may be further controlled by means known to one skilled in the art so as to externally manipulate the shock absorber portion (C' over D') enabling the absorber shock (C' over D') to be customized or tuned for different vehicles and applications. As before, the released air may also be diverted to a tank (not shown) as compressed air.

(23) Chambers C' and E' would automatically compress air as the gas spring is compressed and draw air in as the air spring is extended. This air can also be released to atmosphere through similar one-way flow control valves, thereby providing more or different spring dampening. Chambers C' and E' could thus also be used as compressors.

(24) Chambers C' and E' could work in tandem with chambers B' and D'. Instead of chambers C' and E' releasing air under compression to atmosphere, some air could be momentarily diverted to B' and D'. Pressurizing chambers B' and D' would cause the air spring to resist rebounding, before the pressurized air from chambers B' and D' is released to atmosphere, thereby increasing oscillation control of the shock absorber action.

(25) In extreme off-road conditions chambers C' and E' may be used to provide pressure to chambers B' and D' to augment or increase the compression travel, before the air is released to atmosphere. For example if the right front tire of the vehicle is climbing a very large rock, pressurizing chambers B', D' would force the spring chamber A' to compress further than normal, thereby keeping the right corner of the vehicle from being pushed up by the rock. This would keep the vehicle more level and prevent the opposite tire (in this case, the left front tire) from being lifted off the ground. This would then reduce the rock impact from being transferred to the vehicle occupants. It would also keep the vehicle body more level while allowing the suspension to further articulate and would help keep the tires more in contact with the ground for better traction, in other words acting like a softer spring. Thus over-driving the gas spring gives the corresponding wheel's suspension a plush or instantaneously softer spring rate.

(26) The same would happen on vehicle front end droop, e.g. where the tire encounters a big hole, when chambers B' and D' are used to pressurize chambers C' and E'. The tire would be forced down into the hole rather than just left hanging up in the air like on a conventional suspension. This will assist in maintaining better ground contact, traction, stabilizing the suspension, keep vehicle more level, minimize the tipping characteristics of the vehicle when one tire is hanging.

(27) Chambers C' and E', and B' and D' could also be closed completely by a steering sensor (not shown) which detects vehicle cornering, and then causes the air spring to stiffen, thereby

minimizing vehicle body roll in corners or during avoidance maneuvers. All of these functions are provided in the spring of FIG. 4 by controlling the air flow between the chambers either mechanically or with a computerized system.

(28) The option also exists to transfer air to other cylinders thereby greatly improving/changing the possibilities of the system. Moving air to other cylinders, for example located in other corners of the vehicle, allows influence over every aspect of a vehicles handling.

(29) This system could counter-act the effects of gravity on vehicle steering and off-road performance, for example providing tilt to the vehicle in corners, and provide both a road racing suspension and an off-road racing suspension. By continually drawing in and expelling external air the combination air spring/shock absorber of FIG. 4 should prevent heat build up and even cool the air spring. This system may be cheaper, lighter, more compact, more tunable than is conventionally known, and may increase vehicle performance, save fuel, and improve handling.

(30) One implementation of the embodiment of FIG. 4 is adapted for use as suspension for a snowmobile.

(31) The shock absorber **406** (chambers C' over D') is resilient along the centroidal axis B relative to the gas spring **408** (chambers A', C' over B', D') upon a force acting in direction C on the lower end of the combination gas spring and shock absorber **400**.

(32) Shock absorber **406** includes piston **418** sliding along axis B within cylinder **410**. Cylinder **410** is itself slidably journaled along splines **412**, parallel to axis B, and annular seals **406a** in the base cylinder **414** of gas spring **408**. The upper end of base cylinder **414** is mounted to a piston **416**. Piston **416** extends around cylinder **410** and floats slidably along the interior surface of the cylindrical housing wall **408e** of gas spring **408** so as to translate in direction D. Annular seal **416a** on piston **416** seals against the housing wall **408c** of gas spring **408**.

(33) Within shock absorber **406**, piston **418** is mounted on shaft **420**. Piston **418** separates chambers C' and D'. Shaft **420** extends along axis B through Chamber D' and slidably through an aperture in base **410a** of cylinder **410**, sealed by annular seal **410b**. Collar **424** may be rotatably mounted in bearings **426**, and is mounted to the upper end of the cylinder **410** so as to extend along axis B. Gas spring **408** may be mounted to the frame of the vehicle as shown by way of example in FIG. 5.

(34) Collar **424** provides a gas conduit for gas entering or leaving chamber C'. The flow of gas entering or leaving chamber C' is regulated by valves **428**.

(35) Gas entering or leaving annular chamber A', which extends around cylinder **410**, is regulated via gas port **408a**. Gas port **408a** is used to increase or decrease gas pressure in chamber A', and is connected to a gas, such as air, pump or the like (not shown).

(36) Gas entering or leaving annular chamber B' is regulated via gas port **408b** and valve **402**. Gas entering or leaving annular chamber D' is regulated via gas duct **420a** in shaft **420** and valve **404**. Gas entering or leaving annular chamber E' is regulated via duct **420b**. Ducts **420a** and **420b** extend through and along shaft **420** and through the lower end **414a** of cylindrical base **414**.

(37) Small apertures **430**, which may for example be threaded so as to accept correspondingly threaded flow adjustment screws (not show), may be provided in pistons **416**, **418** and in lower end **414a** of base cylinder **414**.

(38) Thus it may be seen that pistons **416**, **418**, mounted on the upper end of, respectively, base cylinder **414** and shaft **420**, move in unison within the housing of gas spring **408** and shock absorber cylinder **410**, respectively, as both base cylinder **414** and shaft **420** are mounted on lower end **414a**. Base cylinder **414** translates along axis B, sliding over seal **414b** mounted in the perimeter of the aperture in annular floor **408d**.

(39) In the example of FIG. 4, air leaving chamber C' may be used to add pressure to chamber D'. Valve **428** may also release air to atmosphere, for example during slowing of the vehicle, to assist in stabilizing the vehicle during cornering in the case of for example a four-wheeled vehicle.

(40) Applying suction (negative pressure) by withdrawing air from chambers A', C' while



pressurizing chambers B', D' acts to adjust ride height, and for example in a four wheeled vehicle may be used to actively raise one wheel to assist in crossing obstacles.

(41) In FIG. 5, wherein the embodiment of FIG. 4 is shown adapted for use on a snowmobile, steering inputs are through the rod **432** coupled to collar **424**. Ski **434** is mounted under lower end **414a** of base cylinder **414**. Impacts to ski **434** during travel of the snowmobile are thus taken up by shock absorber **406** (whether or not acting to dampen or acting as a compressor, or both) and the gas spring **408**. Force from the impact to the ski which is not dampened or absorbed is passed to the snowmobile frame **436** which is clamped or otherwise mounted onto gas spring **408**. Splines **412** in base cylinder **414**, which now acts as a splined steering sleeve, provide for telescoping of the shock absorber cylinder **410** in the steering sleeve. Thus, the snowmobile may be steered during receiving, dampening and absorbing shocks or impacts to the ski during travel.

(42) The use of the valves allows locking-up and unlocking at least the gas spring upon steering inputs in real time to replace the use of a sway bar.

## Claims

1. A combination gas spring and shock absorber apparatus comprising: a vented gas spring housing comprising at least one port for venting, a vented shock absorber housing slidably mounted within the gas spring housing, a shock absorber piston concentrically mounted within a gas spring piston, a base housing slidably mounted in the gas spring housing so as to extend a distal end of the base housing into the gas spring housing, a shaft extending through the base housing and, into the shock absorber housing the shaft having a free end slidably extending from the base housing into the shock absorber housing, the shaft comprising a bypass line with a bypass valve for venting the shock absorber housing, the shock absorber piston mounted in the shock absorber housing on the free end of the shaft, the gas spring piston mounted in the gas spring housing on the distal end of the base housing, wherein the shock absorber piston is fluidically sealed within and against, for sealed sliding translation in and along, the shock absorber housing, and wherein the gas spring piston is fluidically sealed within and against the gas spring housing on an outer perimeter of the gas spring piston and is fluidically sealed against the shock absorber housing, for sealed sliding translation in and along the gas spring housing and along the shock absorber housing respectively, and wherein the base housing is fluidically sealed for sealed telescopic translation of the base housing relative to the gas spring housing.
  2. The apparatus of claim 1 wherein the gas spring housing and the shock absorber housing are cylindrical and having a common centroidal axis, and wherein the translation of the shock absorber housing and base housing is along the common centroidal axis.
  3. The apparatus of claim 2 wherein the shaft lies along the centroidal axis.
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