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(54) **SUSPENSION OF SENSOR COMPONENTS IN HIGH SHOCK APPLICATIONS**

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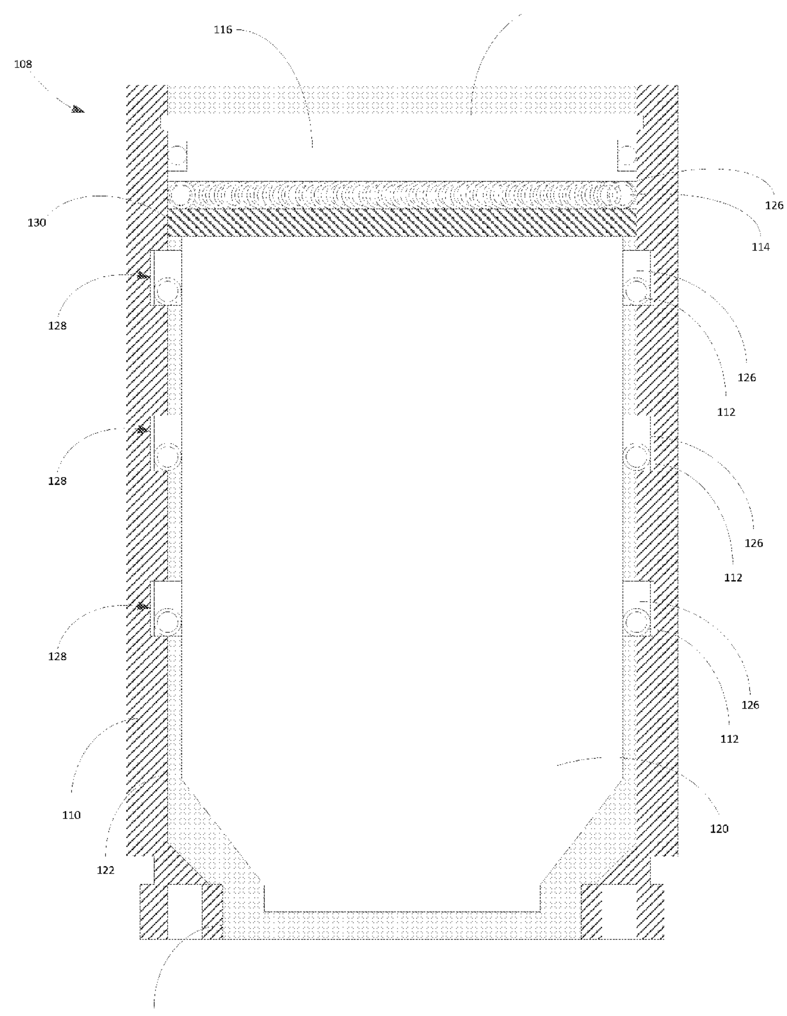
(57) **ABSTRACT**

A suspension assembly for supporting a shock-sensitive component includes an outer housing and a plurality of radial canted coil springs that surround and support the shock-sensitive component. Each of the plurality of radial canted coil springs is preferably a toroid. The exterior of each of the plurality of radial canted coil springs is in contact with the outer housing and the interior of each of the plurality of canted radial canted coil springs is in contact with the exterior of the shock-sensitive component. The radial canted coil springs dampen mechanical shock and vibration applied in a lateral direction. The suspension assembly optionally includes an axial canted coil spring that dampens mechanical shock in the axial direction. The outer housing may include grooves that locate the radial canted coil springs within the suspension assembly.



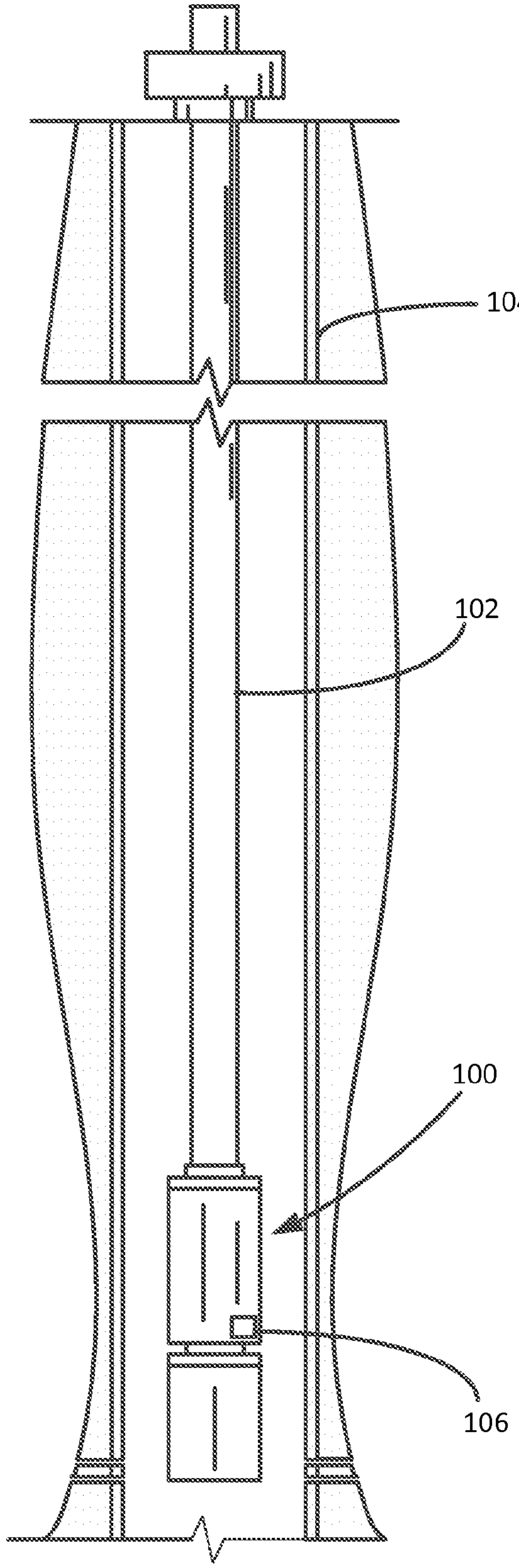
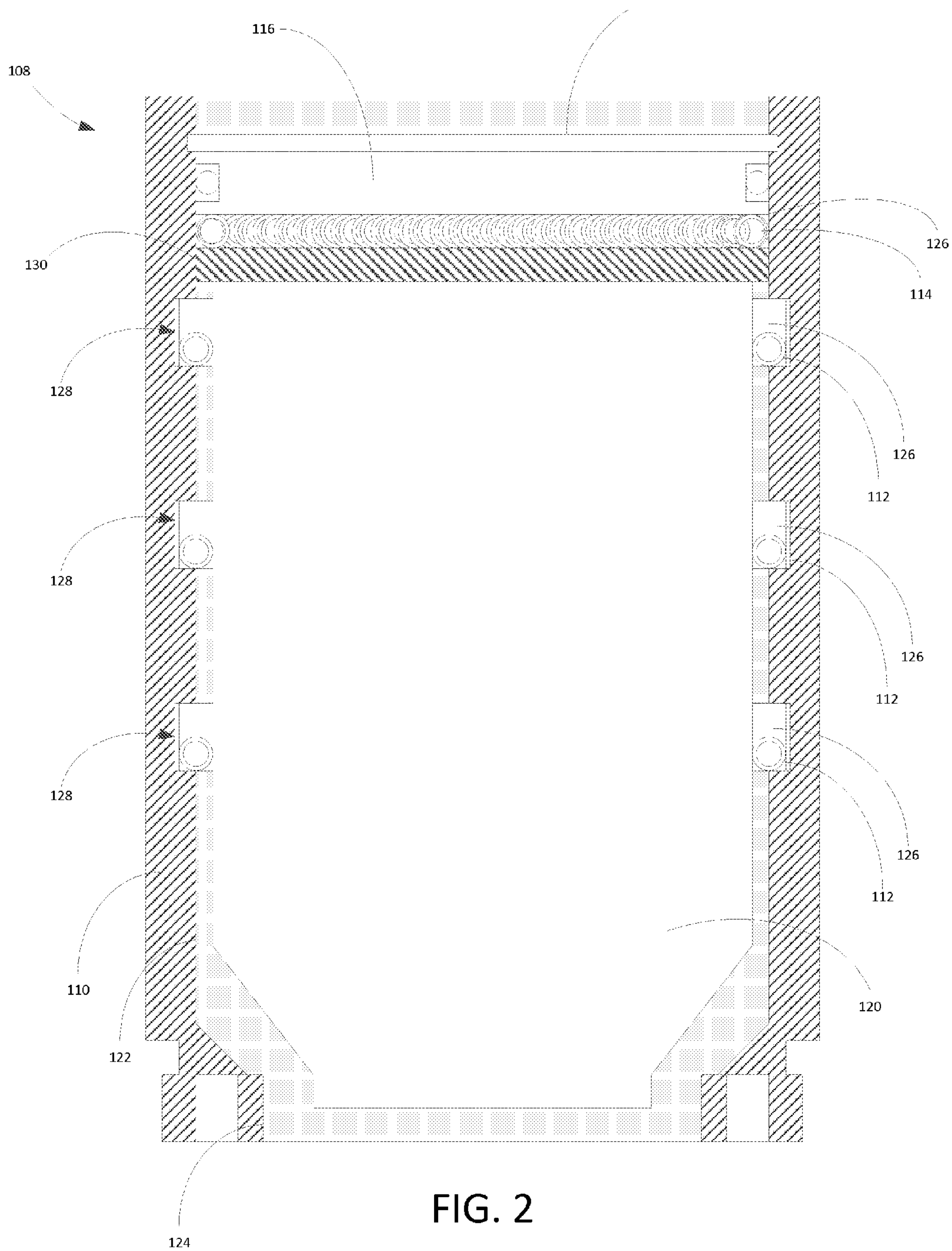


FIG. 1


116
108
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126
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128
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112
110
120
122
124

FIG. 2

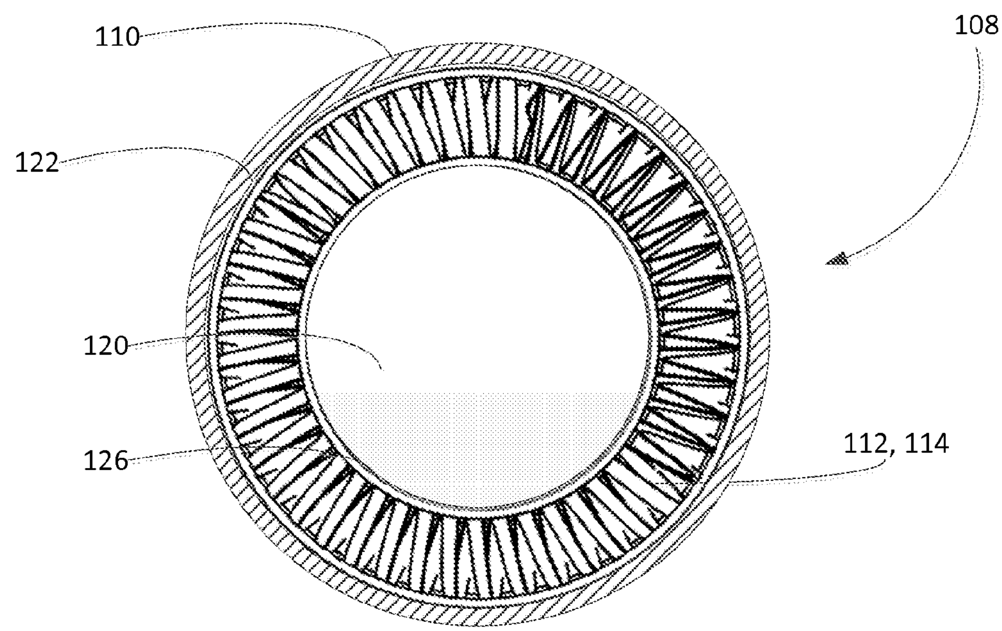

FIG. 3

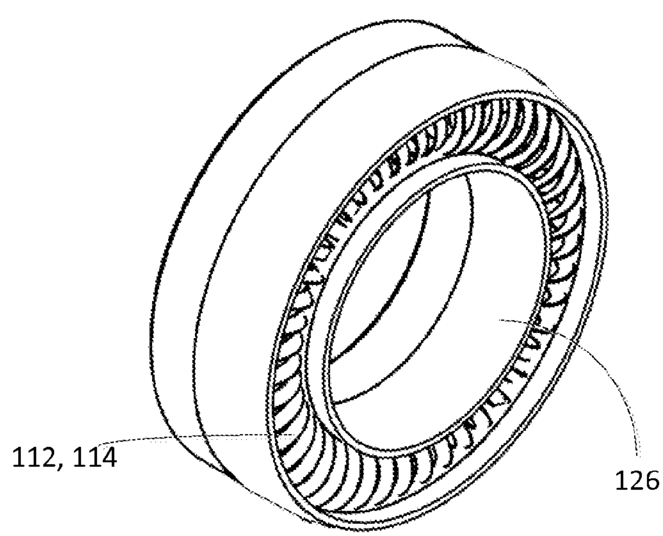

FIG. 4

SUSPENSION OF SENSOR COMPONENTS IN HIGH SHOCK APPLICATIONS

FIELD OF THE INVENTION

[0001] This application relates generally to sensors and sensitive instruments and more particularly, but not by way of limitation, to a suspension system for supporting sensor components that resists shock and vibration.

BACKGROUND

[0002] Sensors are often susceptible to damage or performance degradation when exposed to mechanical shock and vibration. In downhole applications, sensor components must be made to withstand inhospitable conditions that include elevated temperatures, pressures and mechanical shock. Fragile sensor components must be suspended in a manner that will protect them from damage or performance failures when exposed to shock or vibration.

[0003] In the past designers have suspended sensor components with leaf springs and wave springs to dampen shock and vibration. Although generally accepted, the use of leaf springs and wave springs complicates the manufacturing process and may produce inconsistent results. Accordingly, there is a need for an improved mechanism for suspending sensor components in a downhole environment. It is to this and other needs that the preferred embodiments are directed.

SUMMARY OF THE INVENTION

[0004] Preferred embodiments of the present invention include a suspension assembly for supporting a shock-sensitive component includes an outer housing and one or more radial canted coil springs that surround and support the shock-sensitive component. Each of the plurality of radial canted coil springs is preferably a toroid. The exterior of each of the plurality of radial canted coil springs is in contact with the outer housing and the interior of each of the plurality of canted radial canted coil springs is in contact with the exterior of the shock-sensitive component. The radial canted coil springs dampen mechanical shock and vibration applied in a lateral direction. The suspension assembly optionally includes an axial canted coil spring that dampens mechanical shock in the axial direction. The outer housing may include grooves that locate the radial canted coil springs within the suspension assembly.

[0005] In another preferred embodiment, the present invention includes a downhole instrument for measuring a condition in a wellbore. The downhole instrument includes a sensor module, which in turn includes a sensor and a suspension assembly that supports to sensor within the sensor module. The suspension assembly preferably includes an outer housing that contains the sensor, an annulus between the interior surface of the outer housing and the sensor, and a plurality of radial coiled springs. Each of the plurality of radial coiled springs preferably comprises a toroidal coiled spring that is positioned within the annulus between the outer housing and the sensor. The suspension assembly optionally includes an axial coiled spring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is an elevational view of a downhole instrument constructed in accordance with a preferred embodiment.

[0007] FIG. **2** is cross-sectional elevational view of the suspension assembly of the downhole instrument of FIG. **1**.

[0008] FIG. **3** is cross-sectional top view of the suspension assembly of the downhole instrument of FIG. **2**.

[0009] FIG. **4** is a perspective view of a toroidal canted coil spring of the suspension assembly of FIGS. **2** and **3**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0010] In accordance with a preferred embodiment of the present invention, FIG. **1** shows an elevational view of a downhole instrument **100** attached to a deployment cable **102**. The downhole instrument **100** and deployment cable **102** are disposed in a wellbore **104**, which is drilled for the production of a fluid such as water or petroleum. As used herein, the term "petroleum" refers broadly to all mineral hydrocarbons, such as crude oil, gas and combinations of oil and gas.

[0011] The downhole instrument **100** includes a sensor module **106**. The sensor module **106** may include sensors, analyzers, control systems, power systems, data processors and communication systems, all of which are well-known in the art. The deployment cable **102** connects the downhole instrument to surface-based facilities and provides power and communication to and from the downhole instrument **100**. It will be appreciated that the downhole instrument **100** may alternatively be configured as part of a larger downhole assembly. For example, in an alternate preferred embodiment, the downhole instrument **100** is attached to a submersible pumping system or as part of a measurement while drilling system. If the downhole instrument **100** is incorporated within a measurement while drilling system, the instrument **100** may be powered by one or more batteries rather than through an umbilical extending to surface-based power supplies. Although demonstrated in a vertical wellbore **104**, it will be appreciated that downhole instrument **100** may also be implemented in horizontal and non-vertical wellbores. The preferred embodiments may also find utility in surface pumping applications and in other applications in which a sensor or other sensitive component is exposed to the potential of shock and vibration.

[0012] Turning to FIGS. **2** and **3**, shown therein are elevational and top cross-sectional views, respectively, of a suspension assembly **108** constructed in accordance with a preferred embodiment. In the presently preferred embodiment, the suspension assembly **108** is incorporated within the sensor module **106**. The suspension assembly **108** preferably includes an outer housing **110**, one or more radial coiled springs **112**, one or more axial coiled springs **114**, a sealed cap **116**, a locking ring **118** and a shock and vibration sensitive component **120**. The space between the interior of the outer housing **110** and the exterior of the component **120** defines an annulus **122**. The outer housing **110** preferably provides an access port **124** for making connections to the component **120**.

[0013] The component **120** is preferably selected from the group of sensitive components that includes scintillators, gamma ray detectors, x-ray detectors, accelerometers, photomultipliers, and other shock-sensitive components. It will be appreciated, however, that the component **120** could alternatively be selected from other mechanical, electrical or electro-mechanical devices and that the component **120** and suspension assembly **108** could be positioned outside the sensor module **106**.

[0014] The radial coiled springs **112** are sized and configured to occupy the annular space between the interior of the outer housing **110** and the exterior of the component **120**. The axial coiled springs **114** are sized and configured to occupy the space between the end of the component **120** and the sealed cap **116**. The radial and axial coiled springs **112**, **114** are preferably toroidal and canted coiled springs that are constructed from a resilient metal. The canted coiled springs preferably exhibit a resilient and substantially uniform force that increases less than conventional springs during deflection. The exterior of each of the radial canted coil springs **112** is in contact with the outer housing **110** and the interior of each of the plurality of canted radial canted coil springs **112** is in contact with the exterior of the component **120**. The suspension assembly **108** optionally includes a force distribution plate **130** positioned between the component **120** and the axial spring **114**. The force distribution plate **130** more evenly distributes the application of forces between the axial spring **114** and the component **120**.

[0015] Turning to FIG. **4**, shown therein is a front perspective view of a particularly preferred embodiment of the radial and axial coiled springs **112**, **114**. In the particularly preferred embodiment depicted in FIGS. **3** and **4**, the radial and axial coiled springs **112**, **114** include a polymer envelope **126** that entirely or partially encompasses the radial and axial coiled springs **112**, **114**. In highly preferred embodiments, the envelope is constructed from polytetrafluoroethylene (PTFE), which is available from a number of commercial sources. The envelope **126** protects the component **120** from direct contact with the radial and axial coiled springs **112**, **114**.

[0016] The outer housing **110** preferably includes one or more grooves **128** at selected locations along the interior of the outer housing **110**. The machined grooves **128** are preferably machined in the outer housing **110** and sized and configured to accept the one or more radial coiled springs **112**. In the particularly preferred embodiment depicted in FIG. **2**, the suspension assembly **108** includes three radial coiled springs **112**, each disposed in a separate groove **128**. The combined use of the radial coiled springs **112** and the grooves **128** facilitates the manufacturing process because the radial coiled springs **112** can more easily be located in the appropriate place within the suspension assembly **108**.

[0017] During use, the radial coiled springs **112** reduce mechanical shock applied from a lateral direction by absorbing a portion of the kinetic energy imparted on the suspension assembly **108**. Similarly, when a shock is applied in the longitudinal direction, the axial coiled spring **114** absorbs a portion of the kinetic energy to reduce the shock applied to the component **120**. The outer housing **110**, the radial coiled springs **112** and the axial coiled springs **114** are preferably sized to permit the component **120** to deflect up to a predetermined threshold amount. Together, the outer housing **110**, radial coiled springs **112** and axial coiled springs **114** provide a durable and resilient suspension system that is cost-effective and easy to manufacture.

[0018] It is to be understood that even though numerous characteristics and advantages of various embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and functions of various embodiments of the invention, this disclosure is illustrative only, and changes may be made in detail, especially in matters of structure and arrangement of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. It will be appreciated by those skilled in the art that the teachings of the present invention can be applied to other systems without departing from the scope and spirit of the present invention.

What is claimed is:

1. A suspension assembly for securing a sensitive component within a shock-resistant housing, the suspension assembly comprising:

an outer housing that contains the component, wherein the outer housing has an interior surface;

an annulus between the interior surface of the outer housing and the sensitive component; and

one or more radial coiled springs, wherein each of the one or more radial coiled springs comprises a toroidal coiled spring that is positioned within the annulus between the outer housing and the component.

2. The suspension assembly of claim **1**, wherein the outer housing comprises one or more grooves along the interior surface and wherein each of the one or more radial coiled springs can be secured within a corresponding one of the one or more grooves.

3. The suspension assembly of claim **2**, further comprising three radial coiled springs positioned in the annulus between the outer housing and the component, wherein each of the three radial coiled springs is a toroidal and canted coiled spring.

4. The suspension assembly of claim **3**, wherein each of the three radial coiled springs further comprises a polymer envelope that at least partially surrounds the radial coiled spring.

5. The suspension assembly of claim **4**, wherein the polymer envelope comprises a polytetrafluoroethylene envelope.

6. The suspension assembly of claim **1**, further comprising:

a cap enclosing a first end of the outer housing; and

an axial coiled spring, wherein the axial coiled spring is captured between the cap and the component.

7. The suspension assembly of claim **6**, wherein the axial coiled spring comprises a toroidal and canted coiled spring.

8. The suspension assembly of claim **7**, wherein the axial coiled spring further comprises an envelope.

9. The suspension assembly of claim **8**, wherein the axial coiled spring further comprises a polymer envelope.

10. The suspension assembly of claim **9**, wherein the component is a sensor.

11. The suspension assembly of claim **9**, wherein the component is selected from the group consisting of scintillators and photomultipliers.

12. A sensor module for measuring a condition in a wellbore, the sensor module comprising:

a sensor; and

a suspension assembly that supports the sensor within the sensor module, wherein the suspension assembly comprises:

an outer housing that contains the sensor, wherein the outer housing has an interior surface;

an annulus between the interior surface of the outer housing and the sensor; and

a plurality of radial coiled springs, wherein each of the plurality of radial coiled springs comprises a toroidal coiled spring that is positioned within the annulus between the outer housing and the sensor.

13. The sensor module of claim **12**, wherein the outer housing comprises a plurality of grooves along the interior surface and wherein each of the plurality of radial coiled springs can be secured within a corresponding one of the plurality of grooves.

14. The sensor module of claim **12**, wherein the suspension assembly of further comprises:

a cap enclosing a first end of the outer housing;

a force distribution plate in contact with the component; and

an axial coiled spring, wherein the axial coiled spring is captured between the cap and the force distribution plate.

15. The sensor module of claim **14**, wherein the axial coiled spring comprises a toroidal and canted coiled spring.

16. A suspension assembly for supporting a shock-sensitive device, the suspension assembly comprising:

an outer housing; and

a plurality of radial canted coil springs, wherein each of the plurality of radial canted coil springs is a toroid and wherein the exterior of each of the plurality of radial canted coil springs is in contact with the outer housing and the interior of each of the plurality of canted radial canted coil springs is in contact with the exterior of the shock-sensitive device.

17. The suspension assembly of claim **16**, wherein each of the plurality of radial canted coil springs further includes a polymer envelope.

18. The suspension assembly of claim **16**, wherein the outer housing further comprises a plurality of grooves extending along the interior surface and wherein each of the plurality of canted coil springs is secured within a corresponding one of the plurality of grooves.

19. The suspension assembly of claim **16** further comprising:

a cap enclosing a first end of the outer housing;

a force distribution plate in contact with the component; and

an axial canted coiled spring, wherein the axial coiled spring is captured between the cap and the force distribution plate.

20. The suspension assembly of claim **19**, wherein the axial canted coil spring further includes a polymer envelope.

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