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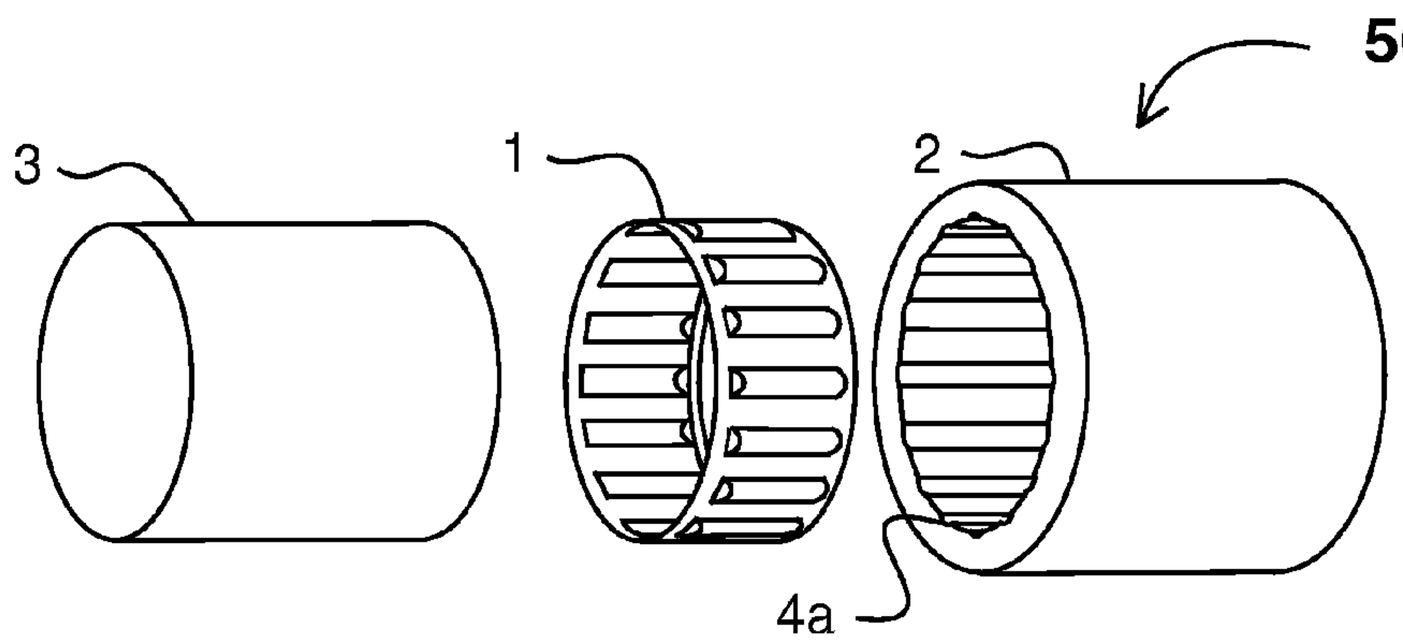
Fig. 3



(57) **Abrégé/Abstract:**
The present invention relates to torque transfer and torque limiting system technology and applications. This invention relates to providing improved torque limiting systems that employ tolerance rings for controlling transmitting power between a single power-input shaft and one or more power-output shafts, which can protect mechanical equipment and drivetrains from damage by mechanical overload. Relating to motor vehicle differentials, the present invention can control differentiation between two power-output shafts, or drive shafts by providing friction internal to said differential and limit "undesirable" slip or differentiation between wheels, as might occur when one wheel encounters a low-traction condition, providing a limited-slip differential.

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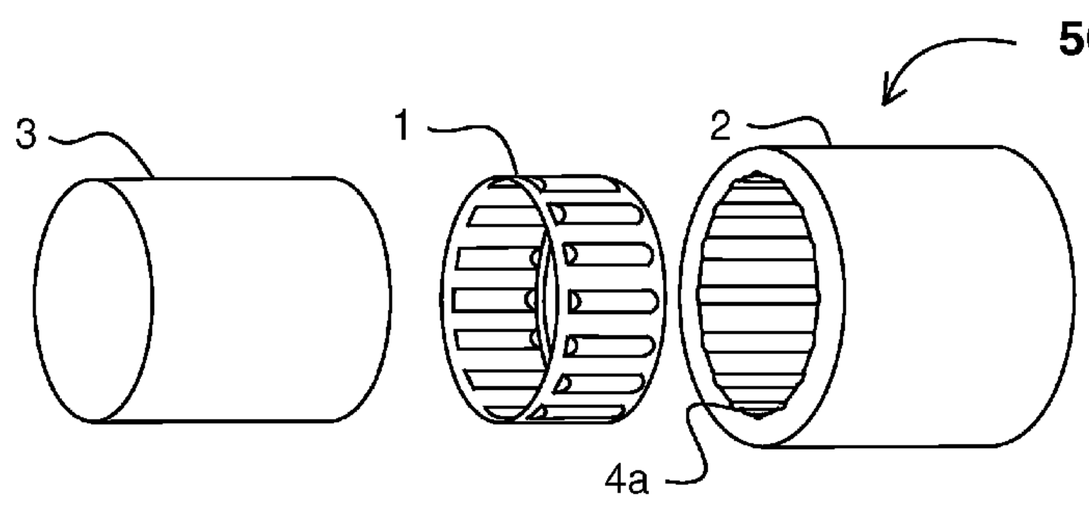
Fig. 3



(57) Abstract: The present invention relates to torque transfer and torque limiting system technology and applications. This invention relates to providing improved torque limiting systems that employ tolerance rings for controlling transmitting power between a single power-input shaft and one or more power-output shafts, which can protect mechanical equipment and drivetrains from damage by mechanical overload. Relating to motor vehicle differentials, the present invention can control differentiation between two power-output shafts, or drive shafts by providing friction internal to said differential and limit "undesirable" slip or differentiation between wheels, as might occur when one wheel encounters a low-traction condition, providing a limited-slip differential.

WO 2015/073118 A3

TORQUE LIMITING SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is related to and claims priority from prior provisional application serial number 61/880,178 filed 09/20/2013, entitled "Limited Slip Differential with Tolerance Rings / Circumferential Clutches", 61/907,386, filed 11/22/2013, entitled "Limited Slip Differential with Tolerance Rings", and is related to and claims priority from prior provisional application Serial Number 61/927,111, filed 01/14/2014, entitled "Mechanical Locking System for Tolerance Rings", the contents of which are incorporated herein by this reference and are not admitted to be prior art with respect to the present invention by the mention in this cross-reference section.

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to torque limiting system technology, torque-slip and torque limiting devices and their application to power transmission assemblies. Such torque limiting devices can protect mechanical equipment from damage by mechanical overload and can be used as torque transferring and limiting devices in various assemblies.

2. Description of the Prior Art

Tolerance Rings, known to the art, are devices capable of providing torque transfer, axial retention and radial loading between mating cylindrical components. When a Tolerance Ring is compressively assembled between said mating cylindrical components, each corrugation provides a spring force resulting in friction. The frictional capacity of the tolerance ring is the resultant force of all the corrugations and the coefficient of friction with the mating components.

Tolerance rings, have a number of advantages, such as being inexpensive, light, simple, durable and allowing rapid device assembly however they are limited in their function when a wide range of mating component material types and frictional capacity is desired.

It is known to the art that a differential is a device that can transfer rotational energy from a single power-input source to two power-output shafts or axles. In the instance of a land vehicle, it can allow differentiation when the outside wheel is required to turn further and faster than the inside wheel when a turn is made. However, to control "undesirable" slip or differentiation between wheels, as might occur when one wheel encounters a low-traction condition, such as mud, snow or ice, it is desirable for the motor vehicle differential assembly to include some provision to limit "undesirable" differentiation.

Many known to the art limited slip differentials utilize viscosity, locking devices, torque sensing gear systems, frictional clutch plates or cones, or other means to limit differentiation and are expensive, complex, heavy, and may exhibit high-frictional loading.

OBJECTS AND FEATURES OF THE INVENTION

More particularly, the present invention can relate to industrial torque limiters and limited-slip differentials, for land vehicles, which provide frictional torque to control differentiation. A primary object and feature of the present invention is to provide a system overcoming the above-mentioned problems.

It is a further object and feature of the present invention to provide such a system permitting independent rotation between the two driven axles, or two output shafts in a fashion that employs tolerance rings as simple, durable and cost-effective means of providing fixed, variable, adjustable and active torque limiting assemblies which provide predetermined amounts of torque internal to the differential, that resist the relative motion of the output shafts so as to desirably distribute torque should traction be compromised on one output shaft or drive wheel.

It is a further object and feature of the present invention to provide versatile, simple, durable, inexpensive system of limited slip differentials:

that permits independent rotation between the two driven axles, or output shafts in a fashion that employs tolerance rings for limiting transmission of torque exceeding a predetermined threshold;

that permits independent rotation between the two driven axles, or two output shafts in a fashion that employs tolerance rings for providing a range of frictional torque-slip values varied by the reaction to angular acceleration of the input energy;

that permits independent rotation between the two driven axles, or two output shafts that employs tolerance rings to improve the function of existing for torque sensing and other types limiting limited-slip differentials;

that permits independent rotation between the two driven axles, or two output shafts in a fashion that employs tolerance rings as simple, durable and cost-effective means of increasing versatility and functionality of torque limiters and limited-slip differentials in automotive and industrial drive lines;

that permits independent rotation between the two driven axles, or two output shafts while imparting a minimum of frictional loading on the power source;

that permits independent rotation between the two driven axles, or two output shafts in a fashion that provides long service life;

that permits independent rotation between the two driven axles, or two output shafts in a fashion that allows for adjustment of the torque limit as a function of one or more parameters.

that employs tolerance rings, which function durably and consistently in the elastic range of their material;

that has configurations of axial grooves which can provide increases or decreases in frictional torque; or

that employs tolerance rings with fixed, variable, adjustable and active torque-slip values and can durably function under continuous torque-slip working conditions.

It is a further object and feature of the present invention to provide a system having axial grooves which provide mechanical forces that can hold said corrugations in said grooves, and prevent the rotation of the tolerance rings corrugations against a circumferential component.

Notably said grooves can allow said tolerance ring to function reliably at a much wider and previously unavailable ranges of fixed and variable torque-slip values because spring force and friction is not required to prevent destructive rotation of said tolerance ring.

Other object and features of this invention will become apparent with reference to the following descriptions.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings described herein are for illustrative purposes only of selected aspects of the present teachings and not all possible implementations, and are not intended to limit the scope of the present teachings. It is also understood that all figures can be exaggerated for clarity.

Fig. 1 shows an externally corrugated tolerance ring in exploded perspective view relating to a prior art assembly.

Fig. 2 shows an internally corrugated tolerance ring in exploded perspective view relating to a prior art assembly.

Fig. 3 shows an externally corrugated tolerance ring in an assembly in exploded perspective view relating to the present invention

Fig. 4 shows an internally corrugated tolerance ring in an assembly in exploded perspective view relating to the present invention.

Fig. 5 shows a fractional sectional schematic view of one corrugation of an externally corrugated tolerance ring of a fixed value torque limiter.

Fig. 6 shows a graph, relating to the performance envelope of a fixed value torque limiter.

Fig. 7 shows a graph, relating to the installed and working torque values of a fixed value torque limiter.

Fig. 8 shows an annular fractional cross-sectional view of a complete variable value by reaction to angular acceleration torque limiting assembly.

Fig. 9 shows a close-up annular fractional cross-sectional view of a variable value by reaction to angular acceleration torque limiter, without a tolerance ring.

Fig. 10 shows a perspective view of the external cylindrical component of a variable value by reaction to angular acceleration torque limiter, without a tolerance ring and the internal cylindrical component.

Fig. 11 shows a fractional sectional schematic view of one corrugation of an externally corrugated tolerance ring of a variable by reaction to angular acceleration torque limiter.

Fig. 12 shows a graph, relating to the performance envelope of a variable by reaction to angular acceleration torque limiter.

Fig. 13 shows a graph, relating to the installed and working torque values of a variable by reaction to angular acceleration torque limiter.

Fig. 14 shows a fractional axial sectional view of a variable by axial movement torque limiter.

Fig. 15 shows an annular fractional sectional view of a variable by axial movement torque limiter.

Fig. 16 shows a fractional axial sectional view of a variable by axial movement torque limiter.

Fig. 17 shows a fractional sectional schematic view of one corrugation of an externally corrugated tolerance ring of a bi-directional, variable by reaction to angular acceleration torque limiter.

Fig. 18 shows a graph, relating to the performance envelope of a, bi-directional variable by reaction to angular acceleration torque limiter.

Fig. 19 shows a graph, relating to the installed and working torque values of a, bi-directional variable by reaction to angular acceleration torque limiter.

Fig. 20 shows a complete annular fractional cross-sectional view of a complete circumferentially adjustable value torque limiter.

Fig. 21 shows an annular fractional cross-sectional view of the driving ring of the circumferentially adjustable value torque limiter.

Fig. 22 shows an axial fractional cross-sectional view of the driving ring of the circumferentially adjustable value torque limiter.

Fig. 23 shows an annular fractional cross-sectional view of the housing ring of the circumferentially adjustable value by torque limiter.

Fig. 24 shows an axial fractional cross-sectional view of the housing ring of the circumferentially adjustable value torque limiter.

Fig. 25 shows an annular fractional sectional view of a taper bushing torque limiter.

Fig. 26 shows an orthogonal view of a the housing of the taper bushing torque limiter.

Fig. 27 shows an axial fractional sectional view of a the housing of a taper bushing torque limiter.

Fig. 28 shows a sectional view of an actively variable torque limiter.

Fig. 29 shows an orthogonal view of the actively variable torque limiter.

Fig. 30 shows a sectional view of the actively variable torque limiter.

Fig. 31 shows a block diagram of the function of the actively variable torque limiter.

Fig. 32 shows a graph relating to the relationships among tolerance ring height, compression, ring stiffness, and sensitivity to wear.

Fig. 33 shows a graph relating to the relationships among tolerance ring height, compression, ring stiffness, and sensitivity to wear.

Fig. 34 shows a graph relating to the relationships among tolerance ring height, compression, ring stiffness, and sensitivity to wear.

Fig. 35 shows an annular fractional sectional view of a limited-slip differential with a variable value by reaction to angular acceleration internal frictional device.

DETAILED DESCRIPTION OF THE BEST MODES AND PREFERRED EMBODIMENTS OF THE INVENTION

The following description is provided to enable any person skilled in the art to make and use the present invention and sets forth the best modes contemplated by the inventors of carrying out their invention. Various modifications, however, will remain readily apparent to those skilled in the art, since the generic principles of the present invention have been defined herein specifically to provide a Torque Limiting System.

Here, we describe a novel inventive combination of torque limiters using tolerance rings that can be used as industrial torque limiters and be applied to open differentials, to limit differentiation.

There are two basic types of automotive differential, the Standard or "open" and Limited-slip type differentials. Both are well known to the art and they have the benefit of many years of development. Both are very simple in their function. The first is transmitting power from a single power source to two driven axles, or output shafts. The second is permitting independent rotation, or differentiation between the two driven axles, or output shafts. Said differentiation occurs when, for example, a land vehicle turns and the outside wheel must travel further and turn faster than the inside wheel.

An "open" differential works well in most situations. However differences in traction between driven road wheels, as in when one wheel is on mud or ice, can cause that driven road wheel to slip, not provide traction. This is because the "open" differential accommodates nearly unlimited differentiation and can send most of the output power to the wheel with the least traction, impairing the vehicle's movement.

Limited-slip differentials are well known to the art and can be relatively large, heavy, expensive and complex. However they are still very simple in their function. They, by various means, limit differentiation to provide motive force in traction compromised situations. They are a desirable option in all types of vehicles for both safety and performance but their expense precludes them from being a standard feature.

Many existing industrial torque limiters are complex, large, heavy and expensive. Tolerance rings are known to the art and provide simple, inexpensive torque transfer and limitation. Said tolerance rings have two sides, a corrugated side and a smooth side and can be

made of, but are not limited to, resilient metal or plastic having a split or segmented ring configuration, of varying diameters, having a plurality of circumferentially arranged external or internal corrugations in single or multiple rows, of uniform or varying height and pitch and having a pair of smooth circumferential side rims. Torque limiting assemblies using tolerance rings, limit the maximum amount of torque than can be transmitted between parts of an assembly. When the tolerance ring is compressively located in the annular space between, for example, a shaft and a bore, the corrugations are compressed. Each corrugation acts as a spring and exerts a radial force against the shaft and the surface of the bore, providing a predetermined amount of frictional torque. Preferably there is a linear relationship between compression and friction that determines torque value. Rotation of the housing or the shaft will transmit similar rotation in the other of the shaft or the housing. If said rotational forces are applied such that the input torque is higher than a predetermined threshold value, one will rotate relative to the other, i.e. they will slip.

When such slippage occurs said corrugated side will slip before the smooth side because at least one pressure area of the corrugation side is smaller than a pressure area of the smooth side. When such an occurrence is repeated under working conditions, it can be understood that the corrugations, can cause wear or damage to themselves or the component they are in contact with. Slippage of the smooth side does not generally cause wear. Current practice includes installations where the material receiving the corrugations is soft enough to allow the corrugations to indent and grip the material, however it can be seen that this is not a preferred solution for all conditions or long term performance.

The foregoing issue relating to the slippage of the corrugated side of the tolerance ring relative to the cylindrical component it contacts, can be the primary cause of limited function at low values of spring force or friction.

A further limitation is that said tolerance-ring assemblies can be limited to one predetermined working torque-slip value which may be set by design and manufacture so adjustment, wear, design change and other factors can be difficult or impossible to remedy.

Extensive current research has discovered little knowledge about how tolerance rings function at low torque and torque-slip values and no systems that deal with the problems above.

The present invention provides a range of durable, inexpensive devices that provide fixed adjustable, and variable torque limiters, that increase the versatility and function of tolerance rings and provide a range of durable, inexpensive fixed, variable adjustable, and active limited-slip differentials, thus there is a need for the present invention.

The Figures

Fig. 1 shows an externally corrugated tolerance ring in exploded perspective view in a common prior art assembly. Showing, externally corrugated tolerance ring **1**, external cylindrical component **2**, internal cylindrical component **3**. It is understood that when the torque limit of this assembly is exceeded either the, external cylindrical component **2**, or the internal cylindrical component **3**, will slip relative to the other and the corrugations of externally corrugated tolerance ring **1**, will slip against, external cylindrical component **2,** causing damage and rapid degradation of its predetermined torque value.

Fig. 2 shows an internally corrugated tolerance ring in exploded perspective view in a common prior art assembly. Showing, internally corrugated tolerance ring **1n**, external cylindrical component **2**, internal cylindrical component **3**. It is understood that when the torque limit of this assembly is exceeded either the, external cylindrical component **2**, or the internal cylindrical component **3**, will slip relative to the other and the corrugations of internally corrugated tolerance ring **1n**, will slip against, internal cylindrical component **3,** causing damage and rapid degradation of its predetermined torque value.

Fig. 3 shows an externally corrugated tolerance ring in an assembly in exploded perspective view relating to the present invention. Showing, preferred embodiment **50** of the present invention, externally corrugated tolerance ring **1**, external cylindrical component **2**, internal cylindrical component **3,** constant value axial groove **4a**. It is understood that when the torque limit of this assembly is exceeded either the, external cylindrical component **2**, or the internal cylindrical component **3**, will slip relative to the other. However as there is means to mechanically lock the corrugations of, externally corrugated tolerance ring **1**, to external cylindrical component **2,** by one or more corrugation in, constant value axial groove **4a**, the desired internal cylindrical component **3,** can slip and externally corrugated tolerance ring **1**, will remain mechanically locked to, external cylindrical component **2,** thus providing a torque limiting assembly assembly that is durable, simple and inexpensive**.**

Fig. 4 shows an internally corrugated tolerance ring in an assembly in exploded perspective view relating to the present invention. Showing, internally corrugated tolerance ring **1n**, external cylindrical component **2**, internal cylindrical component **3,** constant value axial groove **4a**. As preceding principles apply it is understood that when the torque limit of this assembly is exceeded either the, external cylindrical component **2**, or the internal cylindrical component **3**. will slip relative to the other.

It is understood that there are many ways to mechanically lock or limit a tolerance ring, using keys, dowels, pins and other methods, without limitation. Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said constant value axial groove **4a,** of a predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 4, and 5 are applicable to all configurations, forms, materials of tolerance rings without limitation.

With a means to mechanically lock the corrugation side of said ring to its desired component damage can be prevented and the reliability and versatility of tolerance ring assemblies can be improved. For example the present invention provides a system that allows for a durable and very wide range of torque transfer and slip values which will be explained further in the teachings.

Fig. 5, 6, 7, show a fractional sectional schematic and two graphs of a fixed value torque limiter, preferred embodiment **50** of the present invention, relating to function, installed and working torque-slip value

Additionally, Fig. 5 introduces force **Ft**, which is a force tangential to internal cylindrical component surface **3a** of internal cylindrical component **3.** Preferably, force **Ft** is generated by internal cylindrical component **3**, as a result of it being driven by a prime mover, in which internal cylindrical component surface **3a,** of internal cylindrical component **3**, slippingly-pushes on externally corrugated tolerance ring **1**, under relative angular acceleration, in either rotational direction, which is constrained by constant value axial groove **4a**.

Because force **Ft** is a vector force directed tangentially to internal cylindrical component surface **3a,** of internal cylindrical component **3**, of a force tangential to internal cylindrical component surface **3a,** of internal cylindrical component cross-section **3**; it translates to a torque equal to **Ft** times the radius of a force tangential to internal cylindrical component surface **3a** of internal cylindrical component **3**.

Fig. 5 shows a fractional sectional schematic view of one corrugation of an externally corrugated tolerance ring of a fixed value torque limiter. Showing, externally corrugated tolerance ring **1**, external cylindrical component **2**, constant value axial groove **4a**, internal

cylindrical component **3**, internal cylindrical component surface **3a**, introducing, compression value scale **0-Y**, corresponding to compression of, externally corrugated tolerance ring **1,** direction of rotation **11,** and force **Ft**.

Explaining Fig. 5, preferably constant-value axial groove **4a**, which provides a predetermined fixed constant torque-slip value under changing angular acceleration. As angular acceleration of the internal cylindrical component **3**, increases or decreases, externally corrugated tolerance ring **1**, can maintain its constant torque-slip value because as compression cannot change neither can torque-slip value. Externally corrugated tolerance ring is mechanically locked by the placement of the corrugation in the groove. Preferably preferred embodiment **50** can function as a device providing a constant value of torque slip in under all rotational conditions in either rotational direction.

Fig. 6 shows a graph, relating to the performance envelope of a fixed value torque limiter. Said graph directly relates to Fig. 5. Introducing torque value scale **0-T**, showing torque-slip value that relates to compression; compression value scale **0-Y,** corresponding to compression of, externally corrugated tolerance ring **1**, not shown, direction of rotation **11.**

Explaining Fig. 6, preferably, constant-value axial groove **4a** shows a constant torque-slip and compression value, which cannot change as angular acceleration of the internal cylindrical component increases or decreases, because compression cannot change. The event is described by the following relationship: at **4a** force **Ft** equals force **4a**. These relative parameters are critical to performance of torque limiting systems described herein—for the reasons explained herein.

As externally corrugated tolerance ring **1,** is mechanically locked by constant value axial groove **4a**, to external cylindrical component **2**, it can reliably transmit fixed predetermined installed torque-slip values from zero to the maximum elastic value of externally corrugated tolerance ring **1,** under continuous working conditions without changes caused by variations of angular acceleration or loss of mechanical grip. Preferably this embodiment is particularly beneficial when a wide possibility of fixed constant predetermined torque-slip values are required and a tolerance ring is required to durably function under fixed value continuous torque-slip working conditions.

It is known to the art that the mechanical forces holding a tolerance rings corrugations in axial groove 4a, can be greater than the tangential force or angular acceleration of internal cylindrical component **3**; therefore the relationship can be, mechanical force **mf** is greater than tangential force **Ft**. Notably axial groove **4a,** can allow externally corrugated tolerance ring **1**, to

function reliably at a much wider and previously unavailable range of torque-slip values because spring force and or friction is not required to prevent unwanted relative rotation.

Fig. 7 shows a graph, relating to the installed and working torque values of a fixed value torque limiter. Additionally Fig. 7 introduces and explains how torque-slip values produced by a tolerance ring change with use over time and introduces the notions of installed torque value, **itv,** the torque value of externally corrugated tolerance ring **1**, when first installed in an assembly and working torque value, **wtv,** the torque value of externally corrugated tolerance ring **1**, after a seating period and their respective relationships.

Showing torque value scale **0-T**, compression value scale **0-Y**, introducing scale **rx1k**, showing revolutions of internal cylindrical component **3,** in increments of one thousand.

Regarding Fig. 7, showing a line relating to changes in torque-slip values. Particularly, Fig. 7 shows torque-slip and compression values beginning at installed torque value **itv**, decreasing to working torque value **wtv**. Showing that after reaching its working torque-slip value, a tolerance ring performing in preferred embodiment **50** can provide a very constant and reliable working torque-slip value under continuous working conditions.

In testing it has been found that, for a lubricated test fixture which simulates the function of a limited-slip differential or torque-limiting device, the installed torque value decreases substantially during the first 1,000 rotations. As an example: installed torque value **itv** is 38 ft-lbs and working torque value **wtv** is 28 ft-lbs at approximately 1k revolutions. The average drop between installed and working torque values in this example is about 25%. Thus, this shows the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

Thus, this test shows that a tolerance ring used in a similar installation and cycled for many thousands of revolutions can provide very consistent and reliable working torque value **wtv**. Those in the art understand that the foregoing research, configurations and descriptions are exemplary in nature and are without limitation.

Thus, Fig. 5. 6. 7. schematic and graphs explain how a system to mechanically lock one or more corrugations of a tolerance ring, by constant value axial groove **4a**, provides a torque limiting device that can simply and reliably provide a predetermined fixed constant and reliable working torque-slip value.

It is understood that there are many ways to mechanically lock or limit a tolerance ring, using keys, dowels, pins and other methods, without limitation**.** Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said constant

value axial groove **4a,** of a predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 5, 6, 7, are applicable to all configurations, forms, materials of tolerance rings without limitation.

Fig. 8, 9, 10, show annular fractional cross-sectional and a perspective view of a variable value by reaction to angular acceleration torque limiting assembly.

Fig. 8 shows an annular fractional cross-sectional view of a complete variable value by reaction to angular acceleration torque limiting assembly. Comprising, externally corrugated tolerance ring **1**, external cylindrical component **2**, internal cylindrical component **3**, minimum value mechanical down ramp stop **8**, down ramp **9**, maximum value mechanical down ramp stop **10**, master mechanical corrugation stop **10a**, and at each end of externally corrugated tolerance ring **1**, and one or more corrugation end stop **17**, direction of rotation **11**—showing a preferred direction of rotation of internal cylindrical component **2**.

Explaining Fig. 8, it shows preferred embodiment **100** that provides a predetermined constant minimum torque-slip value at minimum value mechanical down ramp stop **8** under normal rotational conditions. As angular acceleration of internal cylindrical component **3** increases, preferably externally corrugated tolerance ring **1** is driven "down" down ramp **9** into decreasing clearance between down ramp **9,** and internal cylindrical component **3**, thus causing an increase in torque-slip value.

Thus preferably compression and torque increase until the corrugations reach maximum value mechanical down ramp stop **10**, at which point the torque-slip threshold is reached. Should angular acceleration continue, preferably preferred embodiment **100** functions as a torque limiter thereby providing a predetermined maximum torque-slip value. Preferably because down ramp **9,** has a self-releasing profile and because angular acceleration ceases or becomes negative, externally corrugated tolerance ring **1,** returns to minimum value mechanical down ramp stop **8,** and minimum torque-slip value. Should internal cylindrical component **3**, rotate in reverse direction, not shown, preferred embodiment **100** will produce the same predetermined minimum torque-slip value as is produced at minimum value mechanical down ramp stop **8** under normal relative rotational conditions

Preferably one or more corrugation end stop **17,** are located at opposite ends of externally corrugated tolerance ring **1,** and can limit maximum compression and maximum torque-transfer (predetermined maximum torque-slip value) to a predetermined range. These relative parameters are critical to performance of torque limiting systems described herein—for the reasons explained herein.

Fig. 9 shows a close-up annular fractional cross-sectional view of a variable value by reaction to angular acceleration torque limiter, without a tolerance ring. Showing close-up of Fig. 8 without externally corrugated tolerance ring **1**. This view more clearly shows down ramp **9**. Also, preferably this view shows external cylindrical component **2**, internal cylindrical component **3**, minimum value mechanical down ramp stop **8**, down ramp **9**, and maximum value mechanical down ramp stop **10**; with direction of rotation **11**.

Fig. 10 shows a perspective view of the external cylindrical component of a variable value by reaction to angular acceleration torque limiter, without a tolerance ring and the internal cylindrical component. Showing a perspective view of, external cylindrical component **2**, of Fig. 8 by itself, with, external cylindrical component **2**, minimum value mechanical down ramp stop **8**, down ramp **9**, maximum value mechanical down ramp stop **10**, master mechanical corrugation stop **10a**.

It is understood by those in the art that there is unlimited variation of characteristics of minimum value mechanical down ramp stop **8**, down ramp **9**, and maximum value mechanical down ramp stop **10** and their relationships which can include but are not limited to: long or short, linear or, convex or concave curvatures, gradual or abrupt and of lesser or greater compression.

Preferably embodiment **100** of the present invention is designed to rotate in a counter clockwise direction only, as the profile of the down ramps only allow compression in one direction. Alternatively, preferably, the present invention **100** can be configured to provide torque-slip in either counter clockwise or clockwise but not both rotational directions.

Preferably both external cylindrical component **2** and internal cylindrical component **3** are structured and arranged for rotating in the same angular direction and slippingly-coupled relative to each other. Preferably, these components are structured and arranged in a device such as a differential between a power source and a road wheel of a land vehicle. Preferably, these components are structured and arranged such that angular acceleration can manifest itself as a sudden increased rotational speed, or as a tangential force impulse.

Preferably externally corrugated tolerance ring **1**, is structured and arranged in a housing bore and around a corresponding shaft; or in a groove in a housing bore and around a corresponding shaft; or in a housing bore and in a groove around a shaft; or a combination of

these preferred arrangements, without limitation. Elements of preferred embodiment **100** can be lubricated by any means known to the art.

As stated this configuration of the present invention provides variable torque-slip values in one direction only and provides a fixed constant torque-slip value in the other direction, which can be forward and reverse in relation to a land vehicle or other driven device.

Additionally, preferably, embodiment **100** can be configured with internally corrugated tolerance ring **1a,** (not shown) without limitation, because preceding principles apply.

Fig. 11, 12, 13, show a fractional sectional schematic and two graphs, relating to function, installed and working torque-slip value of a variable value by angular acceleration torque limiter, preferred embodiment **100** of the present invention.

Fig. 11 shows a fractional sectional schematic view of one corrugation of an externally corrugated tolerance ring of a variable by reaction to angular acceleration torque limiter.

Showing, externally corrugated tolerance ring **1**, external cylindrical component **2**, internal cylindrical component **3**, internal cylindrical component surface **3a**, minimum value mechanical down ramp stop **8**, down ramp **9**, maximum value mechanical down ramp stop **10**, compression value scale **0-Y**, and force **Ft,** showing, direction of rotation **11**.

Explaining Fig. 11, preferably under normal relative rotational conditions, minimum value torque-slip output occurs at minimum value mechanical down ramp stop **8**, which produces a predetermined minimum torque-slip value. As angular acceleration of internal cylindrical component **3** increases, externally corrugated tolerance ring **1** is driven into the decreasing clearances between external cylindrical component **2**, internal cylindrical component **3**, and internal cylindrical component surface **3a,** in the direction of rotation **11**, of down ramp **9**. This action causes an increase in compression and torque-slip value. Thus, compression and torque are increased until externally corrugated tolerance ring **1** is pushed to maximum value mechanical down ramp stop **10**, at which point the torque threshold is reached. Should angular acceleration continue, preferably the device functions as a torque limiter and provides a predetermined maximum torque-slip value. Preferably down ramp **9** has a self-releasing profile and, as angular acceleration decreases or becomes negative, externally corrugated tolerance ring **1** can return to its minimum value mechanical down ramp stop **8**, and its normal predetermined constant minimum torque-slip value. Should internal cylindrical component **3**, rotate in reverse

direction, not shown, preferred embodiment **100** will produce the same predetermined minimum torque-slip value as is produced at minimum value mechanical down ramp stop **8** under normal relative rotational conditions.

Fig. 12 shows a graph, relating to the performance envelope of a variable by reaction to angular acceleration torque limiter. Fig. 12 introduces a graph relating to preferred embodiment **100** of the present invention. The graph of Fig. 12 directly relates to Fig. 11 and introduces; point minimum value mechanical down ramp stop **8p**, line down ramp **9p**, point maximum value mechanical down ramp stop **10p**, which directly correspond to; minimum value mechanical down ramp stop **8**, down ramp **9**, maximum value mechanical down ramp stop **10**.

Showing torque value scale **0-T**, compression value scale **0-Y**, a line with; point minimum value mechanical down ramp stop **8p**, line down ramp **9p**, point maximum value mechanical down ramp stop **10p**, direction of rotation **11**.

Explaining Fig. 12, preferably it is understood that as relative angular acceleration increases and decreases the operating envelope of preferred embodiment **100** is defined by; point minimum value mechanical down ramp stop **8p**, line down ramp **9l**, point maximum value mechanical down ramp stop **10p.**

Regarding Fig. 12, the graph establishes the direct relationship between variations of compression and torque-slip value, showing how their increase and decrease are determined by the relative angular acceleration and deceleration of internal cylindrical component **3**, and define the operating envelope of preferred embodiment **100**. Preferably, this relationship is described by the following relationship: at minimum value mechanical down ramp stop **8**, force **Ft** is less than or equal to **F8**; and at maximum value mechanical down ramp stop **10**, force **Ft** is greater than or equal to **F10**. These relative parameters are critical to performance of torque limiting systems described herein—for the reasons explained herein.

Fig. 13 shows a graph, relating to the installed and working torque values of a variable by reaction to angular acceleration torque limiter. Preferably, Fig. 13 comprises a graph directly relating to Fig. 11 showing torque value scale **0-T,** compression value scale **0-Y,** scale **Rx1k**. Introducing, minimum value mechanical down ramp stop installed torque value **8itv**, minimum value mechanical down ramp stop working torque value **8wtv**; relating to minimum value mechanical down ramp stop **8,** line down ramp **9itv** and line down ramp **9wtv,** relating to down ramp **9**; maximum value mechanical down ramp stop installed torque value **10itv**, maximum value of mechanical down ramp stop installed torque value **10wtv**, relating to maximum value down ramp stop **10**. It is therefore understood that the installed and working torque value,

minimum and maximum value mechanical down ramp stops and down ramps correspond to Fig. 11 and 12 and and the principles described herein.

Explaining Fig. **13**, it shows two lines corresponding to installed and working torque value of preferred embodiment **100** and an installed torque value of externally corrugated tolerance ring **1** (not shown), at zero revolutions **8itv**, **9itv**, **10itv.** As revolutions increase installed torque-slip value begins to drop to working torque-slip value**, 8wtv**, **9wtv**, **10wtv**, once working torque value is achieved, working torque value will continue with a very minimal loss of torque and compression for many thousands of revolutions. These relative parameters are critical to performance of torque limiting systems described herein—for the reasons explained herein.

Showing that preferred embodiment **100** can provide very consistent and reliable working torque-slip values. Those in the art understand that he foregoing research, configurations and descriptions are exemplary in nature and do not limit the scope of the present invention in any manner.

Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said, minimum value mechanical down ramp stop **8**, down ramp **9**, maximum value mechanical down ramp stop **10**, of predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 11, 12, 13 are applicable to all configurations, forms, materials of tolerance rings without limitation.

Fig. 14, 15, 16, show fractional sectional views of preferred embodiment **600** utilizing the principles of preferred embodiment **100** of the present invention, which are adapted to provide compression and torque-slip from axial movement of the external cylindrical component.

Preferably preferred embodiment **600** utilizing preceding principles can provide a pre-calculated range of actively variable torques-slip values.

Fig. 14 shows a fractional axial sectional view of a torque limiter. Showing externally corrugated tolerance ring **1**, external compression component **2c**, internal cylindrical component

3, internal cylindrical component surface **3a,** axial compression groove **4b**, housing moving force **mF**, external compression component stop **10x**, and axial holding groove **4c**.

Explaining Fig. 14, it shows preferred embodiment **600** in a configuration that provides zero torque-slip under normal conditions. Axial compression groove **4b** can engage one or more corrugations of externally corrugated tolerance ring **1**, and as external compression component **2c** is moved by housing moving force **mF**, the decreasing dimension between external compression component **2c,** internal cylindrical component **3,** and internal cylindrical component surface **3a,** causes an increase in compression and torque-slip value.

Thus preferably compression and torque-slip increase until said external compression component **2c** reaches external compression component stop **10x**, at which point maximum desired torque-slip value is reached. Preferably preferred embodiment **600** then functions as a torque limiter, thereby providing a predetermined maximum torque-slip value. Preferably because axial compression groove **4a** has a self-releasing profile and or because housing moving force **mF** ceases or becomes negative, torque-slip value returns to zero. Axial holding groove may mechanically limit unwanted axial movement of externally corrugated tolerance ring **1**.

Fig. 15 shows an annular fractional sectional view of a torque limiter. Showing a fractional cross sectional view of the above described embodiment **600** having; externally corrugated tolerance ring **1**, external compression component **2c**, internal cylindrical component **3**, internal cylindrical component surface **3a**, and axial compression groove **4b**.

As preceding principles apply it is understood that preferred embodiment **600** can function within a range of predetermined torque-slip values without limitation. Preferably it is understood that moving force **mF** can originate from any source without limitation.

This embodiment can have a performance envelope similar to Fig. 11, 12, 13. Also preferably it is understood by those in the art that preferred embodiment **600** can be adapted to function with any of the applicable embodiments of the present invention without limitation.

Preferably it is understood by those in the art that the foregoing explanations are exemplary in nature, and are without limitation.

Fig. 16 shows a fractional axial sectional view of a torque limiter. Showing angularly externally corrugated tolerance ring **1b**, external compression component **2c**, internal cylindrical component **3**, internal cylindrical component surface **3a,** axial compression groove **4b**, housing moving force **mF**, external compression component stop **10x**, and axial holding groove **4c**.

Explaining Fig. 16, it shows preferred embodiment **600** in a configuration that provides zero torque-slip under normal conditions. Axial compression groove **4b** can engage one or more

corrugations of angularly externally corrugated tolerance ring **1b**. As external compression component **2c** is moved by housing moving force **mF**, the decreasing dimension between external compression component **2c,** internal cylindrical component **3,** and internal cylindrical component surface **3a,** causes an increase in compression and torque-slip value.

Thus preferably compression and torque-slip increase until said external compression component **2c** reaches external compression component stop **10x**, at which point maximum desired torque-slip value is reached. Preferably preferred embodiment **600** then functions as a torque limiter, thereby providing a predetermined maximum torque-slip value. Preferably because axial compression groove **4a** has a self-releasing profile and or because housing moving force **mF** ceases or becomes negative, torque-slip value returns to zero. Axial holding groove may mechanically limit unwanted axial movement of angularly externally corrugated tolerance ring **1**.

Those in the art can understand that the foregoing configurations are exemplary in nature and without limitation. Said, axial compression groove **4b**, of predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 14, 15, 16 are applicable to all configurations, forms, materials of tolerance rings without limitation.

Fig. 17, 18, 19, show a fractional sectional schematic and two graphs, relating to function, installed and working torque-slip value of a variable value by reaction to angular acceleration bi-directional torque limiter, preferred embodiment **150** of the present invention.

Additionally Fig. 17 shows a bi-directional variant of preferred embodiment **100**, Fig. 14, whose function was described in detail preceding.

Introducing, maximum value negative mechanical down ramp stop **-10**, negative down ramp **-9,** minimum value equilibrium point **eq**, it is understood as preceding principles apply, these are the corresponding parts necessary to the function of preferred embodiment **150** to provide a bi-directional variable torque value by reaction to angular acceleration torque limiter.

Showing a fractional schematic of one corrugation of externally corrugated tolerance ring **1**, external cylindrical component **2**, internal cylindrical component **3**, internal cylindrical component surface **3a**, maximum value negative mechanical down ramp stop **-10**, negative down ramp **-9,** minimum value equilibrium point **eq**, down ramp **9**, maximum value mechanical down ramp stop **10**, compression scale **0-Y**, and force **Ft**.

Additionally Fig. 5A relates the symmetrical linear bi-directional down ramp profile of down ramp **-9** and down ramp **9** to a clearance between internal cylindrical component, internal cylindrical component surface **3a**, internal cylindrical component **3**, and external cylindrical component **2**.

Fig. 17 shows a fractional sectional schematic view of one corrugation of an externally corrugated tolerance ring of a bi-directional, variable by reaction to angular acceleration torque limiter. Explaining Fig. 17, as preceding principals apply, preferably it is understood that preferred embodiment **150** can provide variable torque values by reaction to angular rotation in either rotational direction and minimum value equilibrium point **eq** describes the situation where relative rotation is zero. Furthermore the detailed explanations in the preceding discussion of Fig.'s 14, 15, 16, apply—except in this preferred embodiment **150**, force **Ft** and its associated rotational angular acceleration of internal cylindrical component **3** can be a bi-directional.

Fig. 18 shows a graph, relating to the performance envelope of a, bi-directional variable by reaction to angular acceleration torque limiter.

Showing torque value scale **0-T**, compression value scale **0-Y,** maximum negative value mechanical stop **-10,** negative down ramp **-9**, minimum value equilibrium point **eq**, down ramp **9**, maximum value mechanical stop **10**, showing direction of rotation **11**.

Explaining Fig. 18, preferably it is understood that preferred embodiment **150** can function in either rotational direction and the detailed explanations in the preceding discussion of Fig. 14, 15, 16, , apply—except in this preferred embodiment **150**, force **Ft** and its associated rotational angular acceleration of internal cylindrical component **3** can be bi-directional. The event is described by the following relationship, at **-10** force **Ft** is greater than or equal to **F-10**, at **eq** force **Ft** equals **Feq**, at maximum value mechanical down ramp stop **10**, force **Ft** is greater than or equal to; **F10**. These relative parameters are critical to the performance of torque limiting systems described herein—for the reasons explained herein.

Fig. 19 shows a graph, relating to the installed and working torque values of a, bi-directional variable by reaction to angular acceleration torque limiter. Showing a graph that relates directly to Fig. 17 . As the principles of the difference in installed torque-slip value and

working torque-slip value have been described in detail preceding the the graph will be briefly described.

Showing a graph with line, installed torque-slip value **itv** and line, working torque-slip value **wtv** which represent the differences in installed and working torque value relating to preferred embodiment **150** and that the difference in installed and long term working torque-slip values is approximately 25%. These relative parameters are critical to the performance of torque limiting systems described herein—for the reasons explained herein.

Showing that preferred embodiment **150** can provide a very consistent and reliable variable value by reaction to angular acceleration bi-directional torque limiter. Those in the art understand that the foregoing research, configurations and descriptions are exemplary in nature and are without limitation.

Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said, maximum negative value mechanical stop **-10,** negative down ramp **-9**, minimum value equilibrium point **eq**, down ramp **9**, maximum value mechanical stop **10**, of predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 17, 18, 19, are applicable to all configurations, forms, materials of tolerance rings without limitation.

Fig. 20, 21, 22, 23, 24, show, complete and partial sectional and fractional sectional views of a circumferentially adjustable-value torque limiter **200** utilizing preferred embodiment **50** of the present invention.

Further, Fig. 20, 21, 22, 23, 24, show preferred embodiment **200** of the present invention, a torque-limiting assembly with means of adjusting its internal circumference. This allows for adjusting the compression and torque-slip value of preferred embodiment **50**, providing adjustability of the associated transferring torque to a desired device.

Fig. 20 shows a complete annular fractional cross-sectional view of a circumferentially adjustable value angular torque limiter. Comprising externally corrugated tolerance ring **1**, external cylindrical component driving ring **2a**, internal cylindrical component **3**, internal

cylindrical component surface **3a**, one or more axial groove **4a**, external cylindrical driving ring **2b**, internal cylindrical component **3**, direction of compression **11a,** one or more holes **16**, one or more adjusting screws **31,** and one or more threaded hole **31a.**

Explaining Fig. 20, axial groove **4a** is parallel to the axis of rotation of a predetermined depth and design, which can be cut into the interior bore, by broaching, CNC or additive manufacturing or other processes known to the art, of external cylindrical component driving ring **2a,** and adapted to drivingly engage one or more of corresponding external corrugations of the externally corrugated tolerance ring **1**. Preferably external cylindrical component driving ring **2a**, is of split ring configuration with one or more protruding ears, and is configured in such a manner that its diameter can be reduced by one or more adjusting screw **31**, which cause a clamping force against the protruding ears, decreasing the internal circumference of external cylindrical component driving ring **2a**.

Preferably external cylindrical component driving ring **2a** can transfer torque through its flange or other means to the external cylindrical driving ring **2b**, which preferably is mounted in a limited slip differential or industrial driveline by bolts, not shown, in one or more hole **16,** without limitation.

Fig. 21 shows an annular fractional cross-sectional view of the driving ring of the circumferentially adjustable value torque limiter. Regarding Fig. 21, it shows external cylindrical component driving ring **2a,** with axial groove **4a,** corresponding to one or more corrugations of externally corrugated tolerance ring **1**, not shown, arrows showing direction of compression **11a**.

Fig. 22 shows an axial fractional cross-sectional view of the driving ring of the circumferentially adjustable value torque limiter. Regarding Fig. 22, it shows an axial cross section of Fig. 2B1 with external cylindrical component driving ring **2a**, having one or more axial groove **4a**.

Fig. 23 shows an annular fractional cross-sectional view of the housing ring of the circumferentially adjustable value torque limiter. Regarding Fig. 23, it shows external cylindrical driving ring **2b**, with threaded hole **31a**, for adjusting screw **31**, and one or more hole **16**.

Fig. 24 shows an axial fractional cross-sectional view of the housing ring of the circumferentially adjustable value torque limiter. Regarding Fig. 24 it shows an axial section of external cylindrical component driving ring **2b** with threaded hole **31a**.

Preferably by changing the internal circumferential diameter of external cylindrical component driving ring **2b**, by the compression of adjusting screw **31,** embodiment **200** provides adjustable torque slip values.

Preferably axial groove **4a**, can closely conform to the contour of the compressed corrugations of a tolerance ring and be the depth of, but shall not be limited to, the thickness of the material of the ring used in its application. Thus for example: a ring made of 0.020 inch thick material can have a groove depth of 0.020 inch, and a ring made of 0.006 inch thick material can have a groove depth of 0.006 inch. These relative dimensions are critical to performance of torque limiting systems described herein—for the reasons explained herein. Said axial grooves can be made by CNC machining, additive manufacturing, molding, shaping, milling, or any process known to the art such without limitation and any part of Fig. 20, 21, 22, 23, 24, can be made of metal, plastic, composite or any material without limitation.

Preferably this preferred embodiment **200** of the present invention provides a very simple, inexpensive and reliable torque limiter with accurately adjustable torque-slip values that can compensate for different requirements, changing conditions or wear.

Preferably it is understood by those in the art that preferred embodiment **200** can be adapted to function with preferred embodiment **50** as shown above or with any relevant embodiment of the present invention. Additionally, preferably, embodiment **200** can be configured in many ways without limitation, including with an internally corrugated tolerance ring (not shown) because preceding principles apply.

Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said, constant value axial groove **4a,** of predetermined depth and design, can be cut into the interior bore of external cylindrical component driving ring **2a**, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 20, 21, 22, 23, 24 are applicable to all configurations, forms, materials of tolerance rings without limitation.

Fig. 25, 26, 27, show a taper bushing torque limiter, preferred embodiment **400** of the present invention an adjustable value torque limiter utilizing preferred embodiment **50**.

Showing Fig. 25, 26 27, one type, known to the art, of a compressive type taper bushing, which further on can be known as an taper bushing, which can be configured to connect a power source to a shaft, a pulley to a shaft and or other configurations without limitation. Preferably said taper bushings can have means to reduce their interior circumferential diameter by compression, or expand their outer circumferential diameter by expansion, not shown, and can

have a means to transfer torque. Preferably said a taper bushings can be used by the present invention to accurately control compression and thus torque slip and can transfer torque. Preferably it is understood that Fig. 25, 26, 27, are exemplary and can represent any type of taper bushing or device with means to expand internally or externally on an internal or external component and a means transfer torque and thus, with any type or configuration, without limitation.

Fig. 25, 26, 27, preferably shows fractional sectional views of said adjustable bushing which can also function as a torque-slip assembly in accordance with a preferred embodiment **400** of the present invention.

Preferably said adjustable bushings can use bolts, split rings and tapered collars to effect compression, on their internal pressure rings, further on it is further explained how compression is achieved and torque is transferred.

Fig. 25 shows an annular fractional sectional view of a taper bushing torque limiter. Showing, internal cylindrical component **3**, axial groove **4a**, split-tapered threaded housing **21**, housing slot **21a**, pressure nut **34,** hole **16**, externally corrugated tolerance ring **1**, not shown.

Fig. 26 shows an orthogonal view of a the housing of a taper bushing torque limiter. Showing, split tapered threaded housing **21**, internal cylindrical component **3,** housing slot **21a**, tapered threads **36**, and hole **16**.

Fig. 27 shows an axial fractional sectional view of a the housing of a taper bushing torque limiter. Showing, pressure nut **34**; lock nut **35**, tapered threads **36**, externally corrugated tolerance ring **1**, internal cylindrical component **3**, axial groove **4a**, split-tapered housing **21**, and hole **16**.

Explaining Fig.'s 25, 26, 27, preferably split-tapered housing **21** is circumferentially compressed by the action of compression nut **34**, thus decreasing its interior diameter. Preferably compression on said externally corrugated tolerance ring **1** can be increased or decreased by the action of said compression nut **34**, and thus its torque-slip value controlled. Preferably split-tapered housing **21** can transfer torque slip from internal cylindrical component **3**, which can be a shaft driven by a power source, through its flange **12**. Said flange, which may have other configurations without limitation, can be mounted in a differential or industrial driveline by bolts in one or more hole **16,** or in other devices or configurations without limitation.

It is understood by those in the art that said compressive taper bushing can be adapted to function with any of the applicable embodiments of the present invention without limitation.

Preferably it is understood by those in the art that the foregoing explanations are exemplary in nature, and are without limitation. Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said constant value axial groove **4a,** of a predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 25, 26, 27, are applicable to all configurations, forms, materials of tolerance rings without limitation.

Preferably preferred embodiment **400** of the present invention provides a very simple, inexpensive and reliable torque limiter with accurately adjustable torque-slip values that can compensate for changing requirements, conditions or wear.

Fig. 28, 29, 30, show sectional views of an actively variable torque limiter. Preferred embodiment **500** using a variant of preferred embodiment **400** and fixed value torque limiter preferred embodiment **50**. Said embodiments provide an active system that can be adapted to many industrial and automotive devices including limited-slip differentials.

Fig. 28 shows a sectional view of an actively variable torque limiter. Showing internal cylindrical component **3**, axial groove **4a**, split-tapered smooth housing **21s**, housing slot **21a**, pressure bearing **22**, actuator arm **24**, actuator **25**, actuator arm pivot **26**, externally corrugated tolerance ring **1**, not shown.

Fig. 29 shows an orthogonal view of an actively variable torque limiter. Showing split tapered smooth housing **21s**, housing slot **21a**, internal cylindrical component **3, and** hole **16**.

Fig. 30 shows a sectional view of an actively variable torque limiter.Showing actuator **25**; actuator piston **25a**, actuator force **aF**, pressure bearing **22**, actuator arm **24**, actuator arm pivot **26**, internal cylindrical component **3**, externally corrugated tolerance ring **1**, pressure collar **32,** Belleville washer group **23**, spacer collar **18**, split-tapered smooth housing **21s**.

Explaining Fig. 28, 29, 30, Under normal conditions preferred embodiment **500** can provide a predetermined frictional torque value. When increased frictional torque is needed or unwanted differentiation is detected, preferably by a signal from a ECU or mechanical controlling device, a hydraulic pump or other device, not shown, can create actuator force **aF**. Actuator piston **25a**, moved by actuator force **aF**, preferably moves actuator arm **24,** which

pivots on actuator arm pivot **26**, and moves pressure bearing **22**, which can be similar in configuration to an automobile clutch throwout bearing, which moves pressure collar **32,** which can have a self-releasing tapered inner surface, against the tapered outer surface of split-tapered smooth housing **21s**, thus decreasing the inner circumferential diameter of split-tapered housing **21s**. This increases compression on externally corrugated tolerance ring **1**. When actuator force **aF** ceases, Belleville washer group **23**, provides force to self-releasing taper of pressure collar **32** returning preferred embodiment **500** to its predetermined frictional torque. This embodiment can have a performance envelope similar to Fig. 14, 15, 16 and may be lubricated by any means known to the art without limitation.

Additionally preferably it is known that as preceding principles apply and preferred embodiment **500** provides a pre-calculated range of actively variable torques-slip values; and when properly configured can provide an active limited slip differential. Preferably said active system can have means to provide actuator force **aF**, without limitation.

Also preferably it can provide power transfer in land vehicles without limitation. Also preferably it is understood by those in the art that preferred embodiment **500** can be adapted to function with any of the applicable embodiments of the present invention without limitation.

Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said constant value axial groove **4a,** of a predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Preferably the principles of Fig. 28, 29, 30, are applicable to all configurations, forms, materials of tolerance rings without limitation.

Fig. 31 shows a block diagram of the function of the actively variable torque limiter, Fig. 28, 29, 30.

1. Detecting Increasing unwanted radial velocity differentiation

2. Sending a signal from a sensor to an actuator

3. Actuator creating actuator force moves an actuator arm

4. Moving actuator moves pressure collar against a tapered outer surface of split-tapered smooth housing, thus decreasing the inner circumferential diameter of split-tapered housing.

5. Decreasing the inner circumferential diameter of split-tapered housing increases compression on the corrugated tolerance ring.

6. Increasing compression on said corrugated tolerance ring increases said at least one torque limit of the torque limiting system.

Fig. 32, 33, 34, show three graphs relating to the relationships between tolerance ring height, compression, ring stiffness, and sensitivity to wear. Here, **tr1**, **tr2**, and **tr3** represent installed torque-slip values of externally corrugated tolerance rings.

Fig. 32 shows a graph relating to the relationships among tolerance ring height, compression, ring stiffness, and sensitivity to wear. Showing two lines **tr1**, **tr2**. Here, **tr1** and **tr2** are externally corrugated tolerance rings with uncompressed corrugation heights of 0.050 inch, and are arranged in identical devices with different diametral clearances. Under related test conditions, **tr1** produced 100 ft-lbs at 10% or 0.005 inch compression, **tr2** produces 50 ft-lbs at 10% or 0.005 inch compression. Therefore, **tr1** is considered to be twice as stiff as **tr2**. Thus, these results show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

When **tr1** is installed in a device with a diametral clearance such that it produces a torque-slip value of 50 ft-lbs (at 0.0025 inch compression), it is considered to be near its upper limit of elasticity. In this case, 0.001 inch of wear results in a 40% loss in torque-slip value. (**tr1** delta = (50-30) / 50 x 100 = 40%). Thus, these results show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

When **tr2** is installed in a device with a diametral clearance such that it produces a torque-slip value of 50 ft-lbs (0.005 inch compression), 0.001 inch of wear results in a 20% loss in torque-slip value. (**tr2** delta = (50-40) / 50 x 100 = 20%). Thus, these results show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

In this example the same amount of wear (0.001 inch) results in double the loss in torque-slip for **tr1** as for **tr2**. Therefore it is preferable to select a tolerance ring whose installed torque-slip value is at or near its upper limit of elasticity.

Fig. 33 shows a graph relating to the relationships among tolerance ring height, compression, ring stiffness, and sensitivity to wear. Showing a graph with two lines **tr2**, and **tr3**. Here, **tr2** can be an externally corrugated tolerance ring, with an uncompressed corrugation height of 0.050 inch, and **tr3** can be an externally corrugated tolerance ring with an

uncompressed corrugation height of 0.100 inch. They are identical devices excepting their different diametral clearances. These relative parameters are critical to performance of torque limiting systems described herein—for the reasons explained herein.

Related testing of **tr2** produced 50 ft-lbs at 10% or 0.005 inch compression; and **tr3** produced 50 ft-lbs at 10% or 0.010 inch compression. When **tr2** is installed in a device with a diametral clearance such that it produces a torque-slip value of 50 ft-lbs (at .0025 inch compression), .001 inch of wear results in a 20% loss of torque-slip value (**tr2** delta = (50-40) / 50 x 100 = 20%). When **tr3** is installed in a device with a diametral clearance such that it produces a torque-slip value of 50 ft-lbs (0.010 inch compression), .001 inch of wear results in a 10% loss of torque-slip value, (**tr3** delta = (50-45) / 50 x 100 = 10%). In this example the same amount of wear (.001 inch) results in double the loss of torque-slip for **tr2** as for **tr3**. Therefore it is preferable to select a tolerance ring with the greatest possible corrugation height. Thus, these results show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

Fig. 34 shows a graph relating to the relationships among tolerance ring height, compression, ring stiffness, and sensitivity to wear. Showing a graph with two lines **tr1**, **tr3**. Here, **tr1** is an externally corrugated tolerance ring, with uncompressed corrugation height of 0.50 inch, and **tr3** is an externally corrugated tolerance ring with compression height of 0.100 inch—and are identical devices with except for their different diametral clearances. In this example we are comparing ring **tr1** from Fig. 1A and ring **tr3** from Fig. 1B. Here, **tr1** produces 100 ft-lbs at 10% or 0.005 inch compression. **tr3** produces 50 ft-lbs at 10% or 0.010 inch compression. Thus, these results show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

When **tr1** is installed in a device with a diametral clearance such that it produces a torque-slip value of 50 ft-lbs (at 0.0025 inch compression), it is considered to be near its upper limit of elasticity. In this case, 0.001 inch of wear results in a 40% loss of torque-slip value (**tr1** delta = (50-30) / 50 x 100 = 40%). Thus, these results show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

When **tr3** is installed in a device with a diametral clearance such that it produces a torque-slip value of 50 ft-lbs (.010 inch compression), 0.001 inch of wear results in a 10% loss of torque-slip value (**tr3** delta = (50-45) / 50 x 100 = 10%). In this example the same amount of wear (.001 inch) results in four times the loss of torque-slip for **tr1** as for **tr3**. Thus, these results

show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

Therefore both the beneficial effects of Examples 1 and 2 are additive. It is preferable to select a tolerance ring whose installed torque-slip value is at or near its upper limit of elasticity, and it is also preferable that said tolerance ring also have the greatest possible corrugation height.

Thus, these results show the criticality of configurations and relative dimensions of torque limiting systems described herein—for the reasons explained herein.

Fig. 35 shows an annular fractional sectional view of a limited-slip differential with a variable value by reaction to angular acceleration internal frictional device.

Fig. 35, shows preferred embodiment **300** of the present invention, a limited-slip differential utilizing preferred embodiment **100**, as a frictional device internal to the differential. Specifically this embodiment, efficiently and inexpensively provides a limited-slip differential with a very minimal addition to size, complexity, expense or weight.

Preferred embodiment **300** can be adapted to many types of devices and vehicles and can be placed in any relevant, power transferring position such as, front wheel drive differential, all wheel drive center differential, rear wheel drive rear axle, or in any relevant land vehicle without limitation.

The function of preferred embodiment **100** has been described in detail in preceding Fig. 8, 9, 10, 11, 12, 13, 14, 15, 16, and can provide a predetermined constant minimum torque-slip value under normal road going conditions, which allows easy differentiation. An increasing torque-slip value during angular acceleration; to provide a higher torque-slip value and increased motive power to the vehicle, should a loss of traction situation occur. A fixed maximum torque-slip value should angular acceleration continue. A decreasing torque-slip value, returning to the constant minimum torque-slip value as angular acceleration ceases or becomes negative, and a fixed constant minimum torque-sip value in the reverse direction. All of which limits unwanted differentiation and provides traction under adverse conditions.

Further, describing Fig. 35, it shows a fractional sectional view of a limited slip differential motor vehicle differential. Preferably, differential housing **47,** is securely mounted to an axle or transaxle housing (not shown) and can be in a motor vehicle. Preferably, differential housing **47,** is adapted to rotate in response to rotational torque received from a prime mover and

a drive train; not shown, a first side bearing **56**, side bearing cap not shown, and a second side bearing **57**, side bearing cap not shown, externally corrugated tolerance ring **1**, minimum value mechanical down ramp stop **8**, down ramp **9**, maximum value mechanical down ramp stop **10**.

Preferably, first side gear **48,** is positioned in differential housing **47**, first side gear **48,** is rotationally fixed to first output shaft **50** and second side gear **49** is positioned in differential housing **47**. Preferably, second side gear **49** is rotationally fixed to a second output shaft **51**, one, or more, differential pinion gear **52**, on pinion shaft **54,** securely fixed to differential housing **47**. Preferably said pinion gears are positioned intermediate to first side gear **48**, and second side gear **49,** permitting differentiation.

Preferably, first side gear **48** and second side gear **49** are fashioned to have a frictional area of increased circumferential diameter and area first side gear frictional area **48a** and second side gear frictional area **49a**. As is known to the art, increased circumferential diameter and area provide an increased amount of torque-slip, with decreased wear characteristics, as the pressure area is larger.

Preferably externally corrugated tolerance ring **1**, one or more, can be positioned in each frictional area, which is between first side gear **48**, second side gear **49**, and differential housing **47**. Thus externally corrugated tolerance ring **1**, is positioned circumferentially around first side gear **48**, and between differential housing **47**, and another externally corrugated tolerance ring **1**, positioned circumferentially around said second side gear **49**, and between said differential housing **47**.

Preferably preferred embodiment **300** can relate directly to preferred embodiment **100** of the present invention. Also preferably it is understood that preferred embodiment **300** can be adapted to function with any of the applicable embodiments of the present invention without limitation.

Those in the art can understand that the foregoing configuration is exemplary in nature and without limitation. Said preferred embodiment **100** with, minimum value mechanical down ramp stop **8**, down ramp **9**, maximum value mechanical down ramp stop **10**, of a predetermined depth and design, can be cut into the interior bore of a housing or exterior surface of a shaft, by broaching, CNC or additive manufacturing or other processes known to the art, without limitation. The principles of the present invention also apply to any type of material or configuration of externally or internally corrugated tolerance ring, and its components, rotating in either direction without limitation. Also preferably it can provide power transfer in land vehicles without limitation.

Preferably it is understood by those in the art that the foregoing explanations are exemplary in nature, and do not limit the scope of the present invention in any way.

LISTING OF ELEMENTS

40 preferred embodiment **40**
fixed value tq limiter
screw, key, pin, stop
not used
50 preferred embodiment **50**
fixed value tq lmt
100 preferred embodiment **100**
uni-variable V tq lmt
150 preferred embodiment **150**
bi-variable V tq lmt
200 preferred embodiment **200**
E-Ring with **50**, **100**,and **150**.
300 preferred embodiment **300**
LSD with **100**
400 preferred embodiment **400**
taper bushing with **50**
500 preferred embodiment **500**
active with **50**
600 preferred embodiment **600**
active syncro w/axial
1 externally corrugated tr
1n internally corrugated tr
1a ext corg tr spherical
1b ext corg tr angle
2 external cylindrical comp
2a ext/cyl/comp/driving ring
2b housing ring
2c external compression comp
3 internal cylindrical comp
3a int cyl compnt surface
4a const V axial groove
4b const V axial ramp
4c axial holding groove
8 min V mech down ramp stop
-8 min V neg down ramp stop
8itv installed tq V
8wtv working tq V
9 down ramp
-9 negative down ramp
9itv installed tq V
9wtv working tq V
10 max V mech down ramp stop
-10 max V neg down ramp stop
10itv installed tq V
10wtv working tq V
10a housing corrugation stop
10b housing
11 direct of rotation
11a direct of comp arrow
11b actuator force
16 hole
17 corrugation Stop
18 spacer collar
21 split-tapered threaded housing
21a housing slot
21s split tapered smooth housing
22 Pressure Bearing
23 Belleville washer group
24 actuator Arm
25 actuator
25a actuator piston
26 actuator arm pivot
31 adjusting screw
31a threaded hole
32 Pressure collar
34 pressure nut
35 lock nut

36 tapered threads
47 differential housing
48 first side gear
48a first side gear frictional area
49 second side gear
49a second side gear frictional area
50 first output shaft **51** second output shaft
52 differential pinion gear
54 pinion shaft
56 side bearing
57 side bearing
eq min V equilib point
10wtv min V M d r work Tq V
Ft tangential force
tr1 tol r 1 in Fig. 6
tr2 tol r 2 in Fig. 6
tr3 tol r 3 in Fig. 6

itv installed-torque value
wtv working-torque value
O-T torque value scale
O-Y compression value scale
rx1k scale
8itv min V m d r inst Tq V
8wtv min V m d r work Tq V
9itv d r inst Tq V
9wtv d r work Tq V
10itv min V M d r inst Tq V

CLAIMS

What Is Claimed Is:

1.A torque limiting assembly, comprising:

a center element defined by a circular cross-section and an outer wall;

an intermediate ring element encircling said center element within a central bore formed therein, said intermediate ring element defined by a generally circular cross-section and an inner wall and an outer wall;

an exterior element encircling said intermediate ring element within a generally circular bore formed in said exterior element, said bore defined by an inner wall and said exterior element further defined by an outer wall; and

wherein said center, intermediate and exterior elements are a matched set selected from a group defined by an inner splined set and an outer splined set,

said inner splined set comprising:

the center element outer wall is defined by a plurality of longitudinal grooves in spaced relation around its periphery;

the intermediate element inner wall is defined by a plurality of domes protruding therefrom, said domes configured to reside within said longitudinal grooves in said center element outer wall; and

the exterior element inner wall is defined by a smooth surface, and

said outer splined set comprising:

the center element outer wall is defined by a smooth surface;

the intermediate element outer wall is defined by a plurality of domes protruding therefrom in spaced relation around its periphery; and

the exterior element inner wall is defined by a plurality of longitudinal grooves configured such that said domes protruding from said intermediate element outer wall reside within them.

2.The torque limiting assembly of Claim 1, wherein at least one said longitudinal groove comprises:

first and second longitudinal sidewalls extending up from the opposing edges of said groove and terminating in first and second stop portions, said first and second longitudinal sidewalls defining relatively unequal heights;

a top wall extending between said stop portions.

3.The torque limiting assembly of Claim 1, wherein at least one said longitudinal groove comprises:

first and second longitudinal sidewalls extending up from the opposing edges of said groove and terminating in first and second stop portions;

a top wall extending between said stop portions, wherein said top wall defines a generally arcuate shape wherein a midpoint defined by said top wall defines a greater distance from a line interconnecting said opposing edges than does the distance between a said stop portion and a said edge at at least one of said sidewalls.

4.The torque limiting assembly of Claim 3, wherein said top wall is defined by a flat ramp portion extending from each of said stop portions, said ramp portions intersecting with one another at said midpoint.

5.The torque limiting assembly of Claim 2, wherein:

said exterior element further comprises at least one longitudinal gap defining a width, said gap extending between said inner wall and said outer wall;

said torque limiting assembly further comprises a gap adjustment mechanism for changing each said gap width.

6.The torque limiting assembly of Claim 5, wherein said gap adjustment mechanism comprises:

an encapsulating ring encircling said exterior element; and

one or more adjustment screws, with each threadedly engaging a threaded bore formed within said encapsulating ring, whereby said one or more adjustment screw can be rotated to add or reduce compressive force on said exterior element to responsively reduce or expand said gap width.

7.The torque limiting assembly of Claim 5, wherein said gap adjustment mechanism comprises:

said exterior element defining a longitudinally-oriented conically-shaped outer wall further defined by threads formed therein; and

one or more threaded nuts engaging said outer wall threads, whereby rotating at least one of said threaded nuts will add or reduce compressive force against said outer wall and responsively reduce or expand said gap width.

8.The torque limiting assembly of Claim 5, wherein said gap adjustment mechanism comprises:

said exterior element defining a longitudinally-oriented conically-shaped outer wall;

one or more collar rings engaging said exterior element outer wall; and

an actuator arm configured to urge one or more of said collar rings longitudinally along said conically-shaped outer wall to add or reduce compressive force against said outer wall to responsively reduce or expand said gap width.

9.The torque limiting assembly of Claim 1, wherein said exterior elements inner wall defines a surface that is sloped along a transverse direction, said transverse direction oriented perpendicular to said longitudinal direction.

10. The torque limiting assembly of Claim 9, wherein said domes define an elongate shape orientated along said transverse direction.

11.A differential assembly, comprising:

a rotatable input shaft assembly;

a first rotatable output shaft assembly mechanically linked to said input shaft whereby rotating said input shaft assembly generates a first rotational force at said first output shaft assembly;

a second rotatable output shaft assembly mechanically linked to said input shaft assembly whereby rotating said input shaft assembly generates a second rotational force at said second output shaft assembly;

a first torque control element associated with said first output shaft assembly, said first torque control element configured to impose force opposing said first rotational force responsive to the speed of rotation of said first output shaft assembly; and

a second torque control element associated with said second output shaft assembly, said second torque control element configured to impose force opposing said second rotational force responsive to the speed of rotation of said second output shaft assembly.

12. The differential assembly of Claim 11, wherein:

said first and second rotatable output shaft assemblies each define:

a center element defined by a circular cross-section and an outer wall; and

an intermediate ring element encircling said center element within a central bore formed therein, said intermediate ring element defined by a generally circular cross-section and an inner wall and an outer wall;

said differential assembly further comprises a housing element element mechanically linked to said input shaft, said housing element encircling said intermediate ring element of both said output shaft assemblies, each within a generally circular bore formed in said housing element, said bore defined by an inner wall; and

wherein said center, intermediate and housing elements are a matched set selected from a group defined by an inner splined set and an outer splined set,

said inner splined set comprising:

the center element outer wall is defined by a plurality of longitudinal grooves in spaced relation around its periphery;

the intermediate element inner wall is defined by a plurality of elongate domes protruding therefrom, said domes configured to reside within said longitudinal grooves in said center element outer wall; and

the housing element inner walls are defined by a smooth surface, and

said outer splined set comprising:

the center element outer wall is defined by a smooth surface;

the intermediate element outer wall is defined by a plurality of elongate domes protruding therefrom in spaced relation around its periphery; and

the housing element inner wall is defined by a plurality of longitudinal grooves configured such that said elongate domes protruding from said intermediate element outer wall reside within them.

13. The differential assembly of Claim 11, wherein said first and second rotatable output shaft assemblies each define:

a center element mechanically linked to said input shaft, said center element defined by a circular cross-section and an outer wall;

an intermediate ring element encircling said center element within a central bore formed therein, said intermediate ring element defined by a generally circular cross-section and an inner wall and an outer wall;

an exterior element encircling said intermediate ring element within a generally circular bore formed in said exterior element, said bore defined by an inner wall and said exterior element further defined by an outer wall; and

wherein said center, intermediate and exterior elements are a matched set selected from a group defined by an inner splined set and an outer splined set,

said inner splined set comprising:

the center element outer wall is defined by a plurality of longitudinal grooves in spaced relation around its periphery;

the intermediate element inner wall is defined by a plurality of elongate domes protruding therefrom, said domes configured to reside within said longitudinal grooves in said center element outer wall; and

the exterior element inner wall is defined by a smooth surface, and

said outer splined set comprising:

the center element outer wall is defined by a smooth surface;

the intermediate element outer wall is defined by a plurality of elongate domes protruding therefrom in spaced relation around its periphery; and

the exterior element inner wall is defined by a plurality of longitudinal grooves configured such that said elongate domes protruding from said intermediate element outer wall reside within them.

14. An improved torque ring assembly, comprising:

a center element defined by an outer wall;

an intermediate ring element surrounding said center element within a central bore formed therein, said intermediate ring element defined by an inner wall and an outer wall;

an exterior element surrounding said intermediate ring element within a bore formed in said exterior element, said bore defined by an inner wall and said exterior element further defined by an outer wall; and

wherein said center, intermediate and exterior elements are a matched set selected from a group defined by an inner grooved set and an outer grooved set,

said inner grooved set comprising:

the center element outer wall is defined by a plurality of longitudinal grooves in spaced relation around its periphery;

the intermediate element inner wall is defined by a plurality of domes protruding therefrom, said domes configured to reside within said longitudinal grooves in said center element outer wall, and further defined by a generally teardrop-shaped cross-section; and

the exterior element inner wall is defined by a smooth surface, and

said outer grooved set comprising:

the center element outer wall is defined by a smooth surface;

the intermediate element outer wall is defined by a plurality of domes protruding therefrom in spaced relation around its periphery, said domes further defined by a generally teardrop-shaped cross-section; and

the exterior element inner wall is defined by a plurality of longitudinal grooves configured such that said domes protruding from said intermediate element outer wall reside within them.

15. The torque ring assembly of Claim 14, wherein said exterior elements inner wall defines a surface that is sloped along a transverse direction, said transverse direction oriented perpendicular to said longitudinal direction.

16. The torque ring assembly of Claim 15, wherein said domes define an elongate shape orientated along said transverse direction.

17. The torque ring assembly of Claim 14, wherein at least one said longitudinal groove comprises:

first and second longitudinal sidewalls extending up from the opposing edges of said groove and terminating in first and second stop portions, said first and second longitudinal sidewalls defining relatively unequal heights;

a top wall extending between said stop portions; and

wherein said exterior element further comprises at least one longitudinal gap defining a width, said gap extending between said inner wall and said outer wall;

said torque ring assembly further comprises a gap adjustment mechanism for changing each said gap width.

18. The torque ring assembly of Claim 19, wherein said gap adjustment mechanism comprises:

an encapsulating ring encircling said exterior element; and

one or more adjustment screws, with each threadedly engaging a threaded bore formed within said encapsulating ring, whereby said one or more adjustment screw can be rotated to add or reduce compressive force on said exterior element to responsively reduce or expand said gap width.

19. The torque ring assembly of Claim 17, wherein said gap adjustment mechanism comprises:

said exterior element defining a longitudinally-oriented conically-shaped outer wall further defined by threads formed therein; and

one or more threaded nuts engaging said outer wall threads, whereby rotating at least one of said threaded nuts will add or reduce compressive force against said outer wall and responsively reduce or expand said gap width.

20. The torque ring assembly of Claim 17, wherein said gap adjustment mechanism comprises:

said exterior element defining a longitudinally-oriented conically-shaped outer wall;

one or more collar rings engaging said exterior element outer wall; and

an actuator element to urge one or more of said collar rings longitudinally along said conically-shaped outer wall to add or reduce compressive force against said outer wall to responsively reduce or expand said gap width.

Fig. 1
PRIOR ART

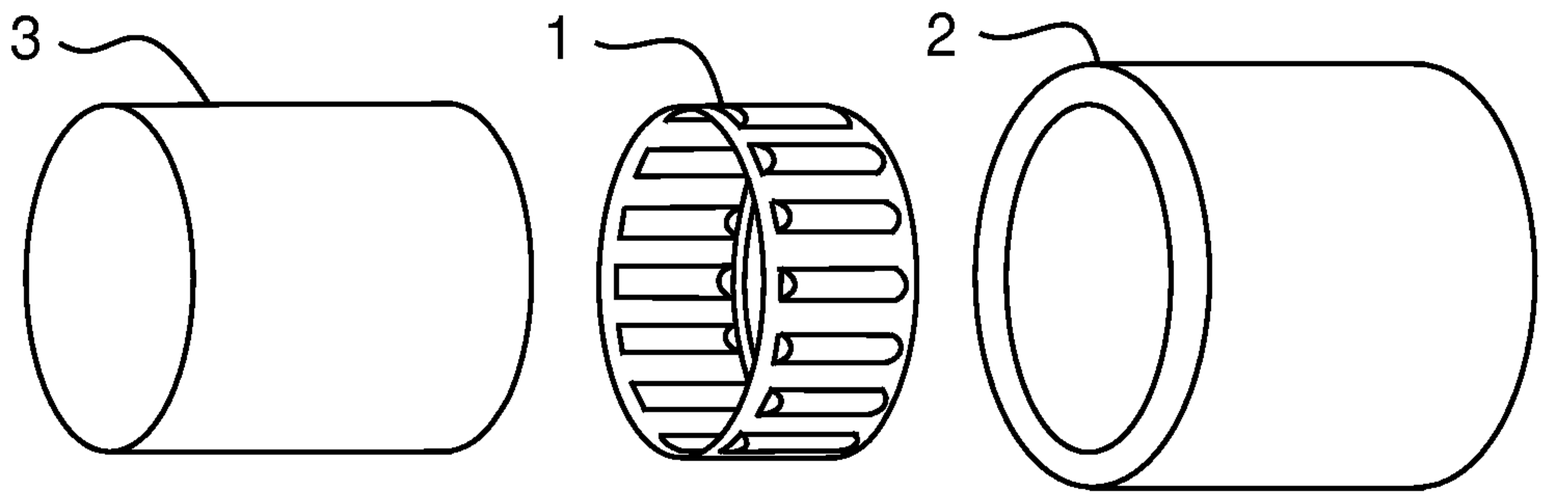


Fig. 2
PRIOR ART

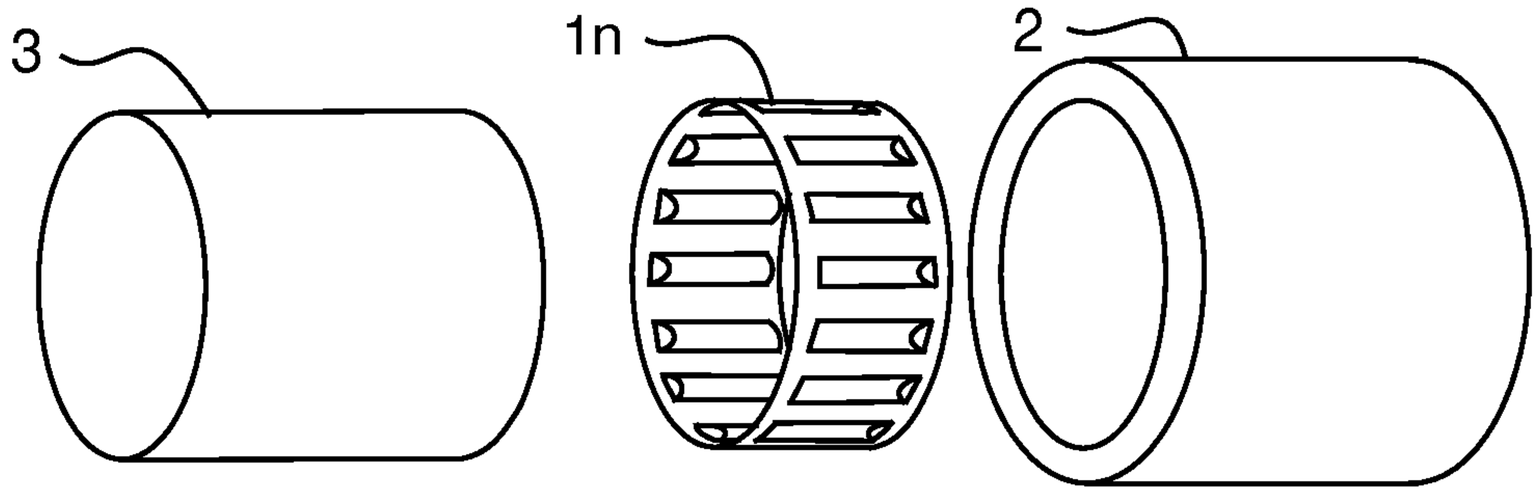


Fig. 3

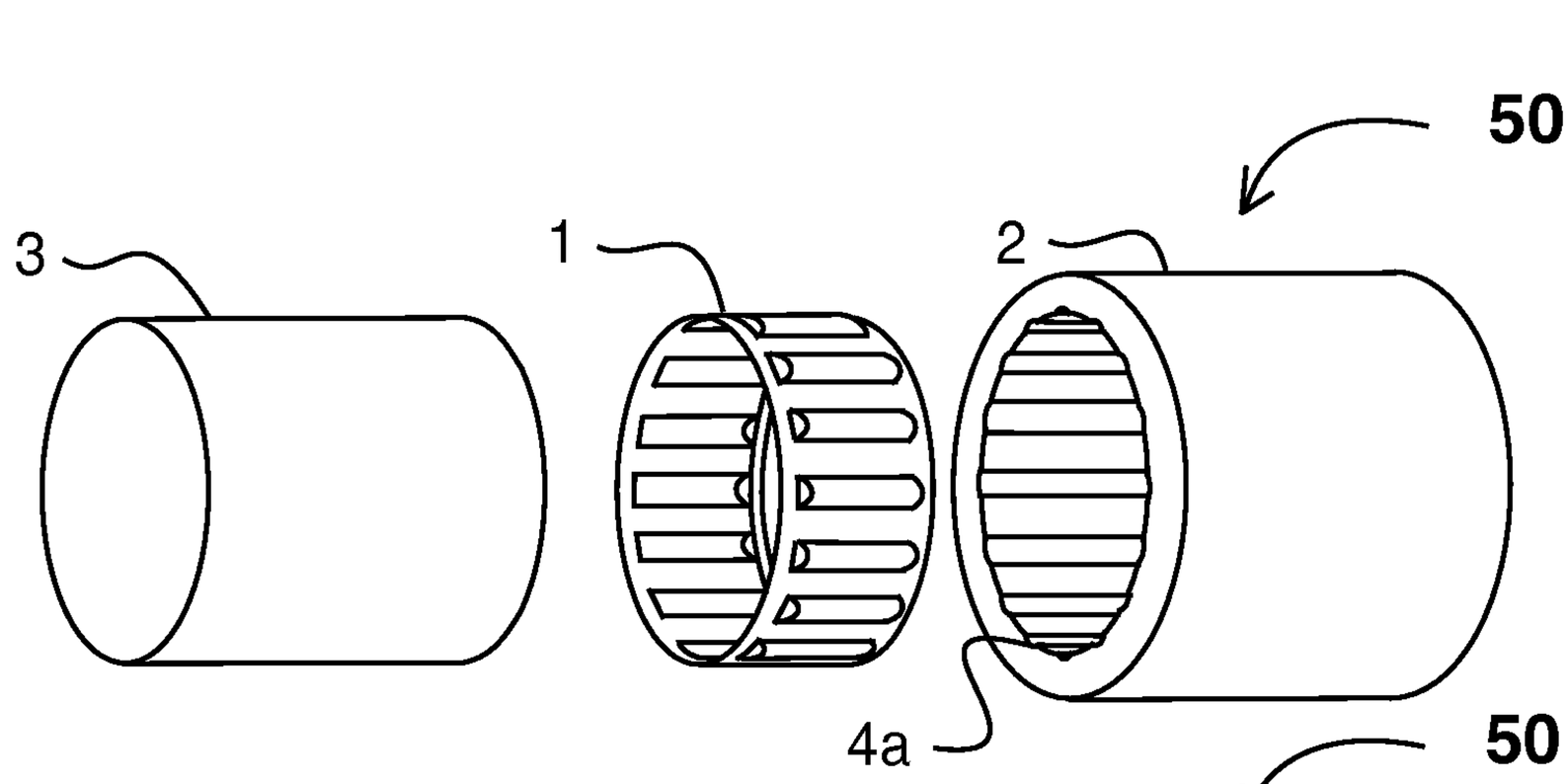


Fig. 4

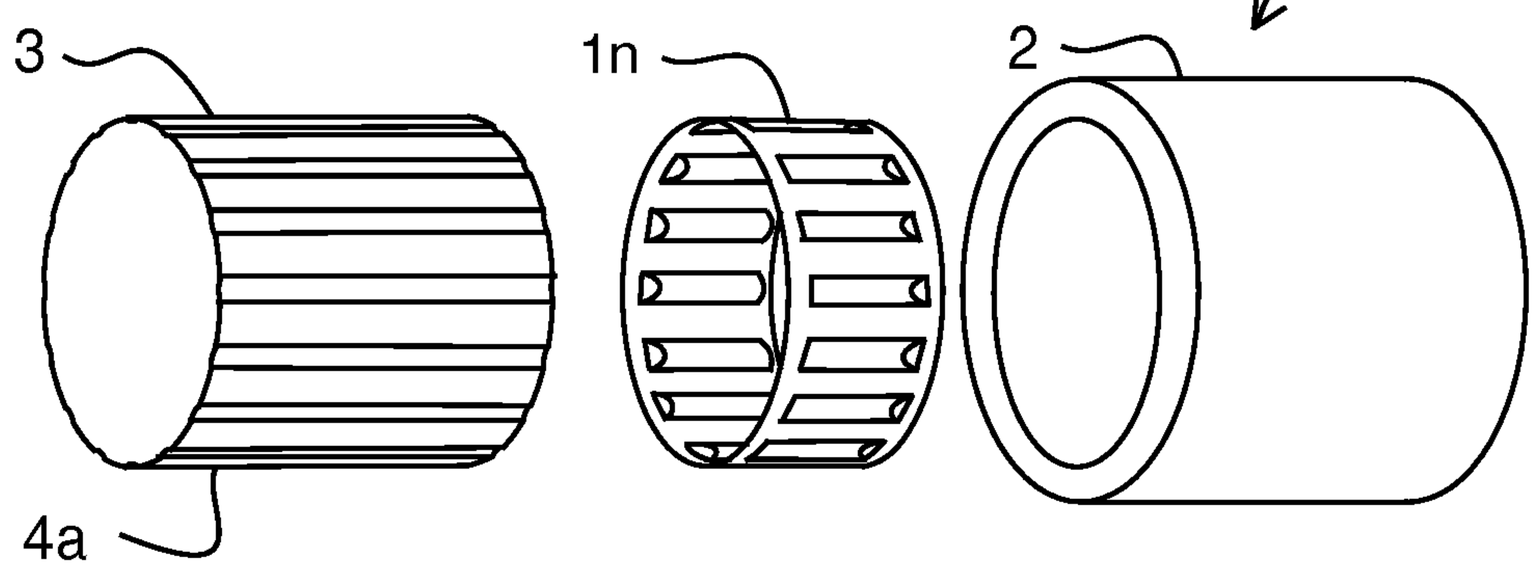


Fig. 5

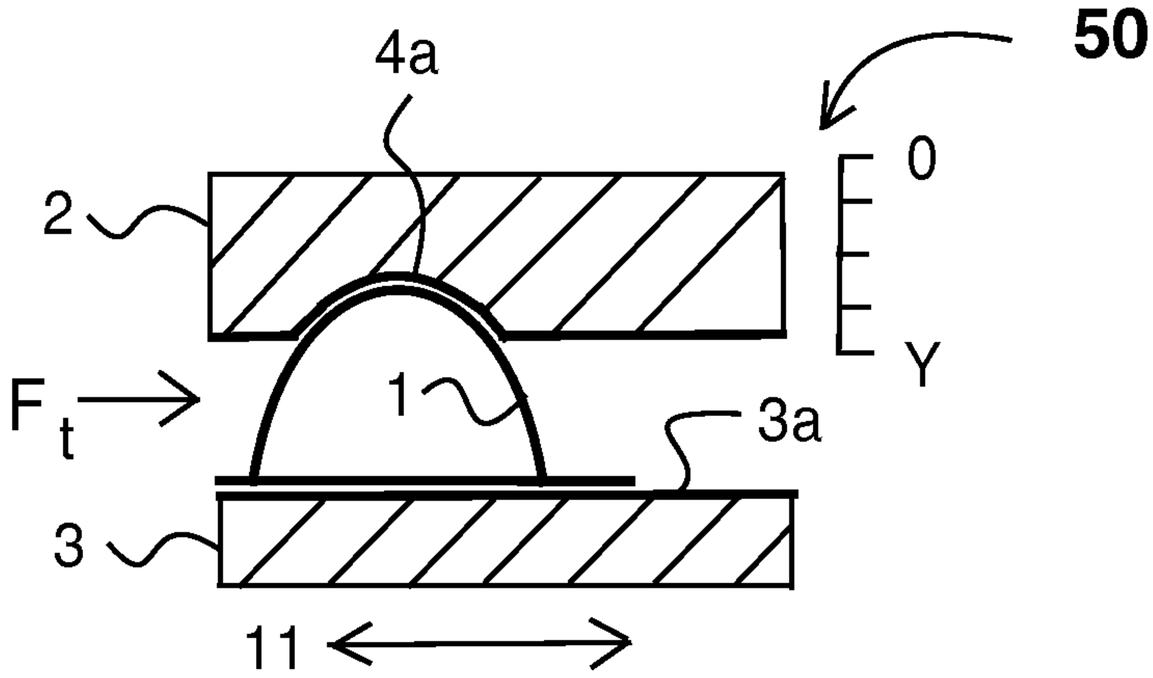


Fig. 6

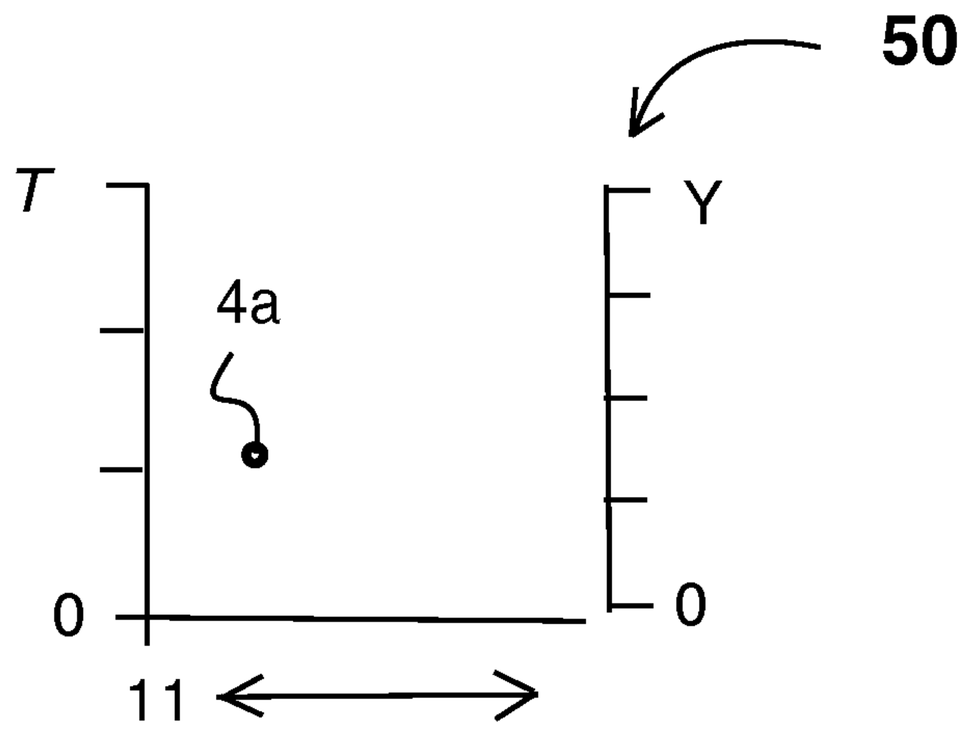


Fig. 7

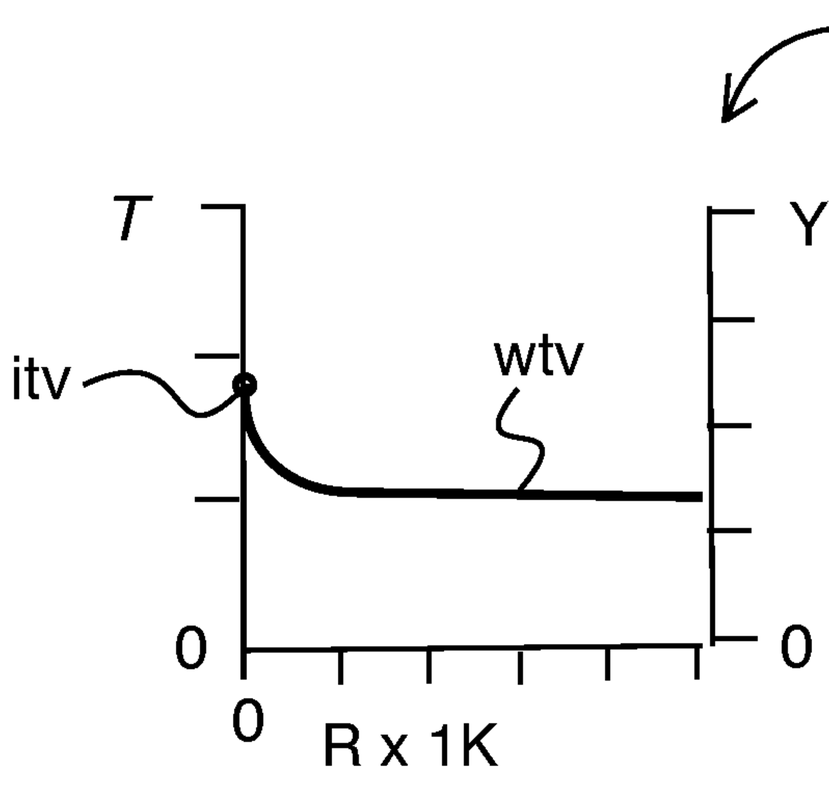


Fig. 8

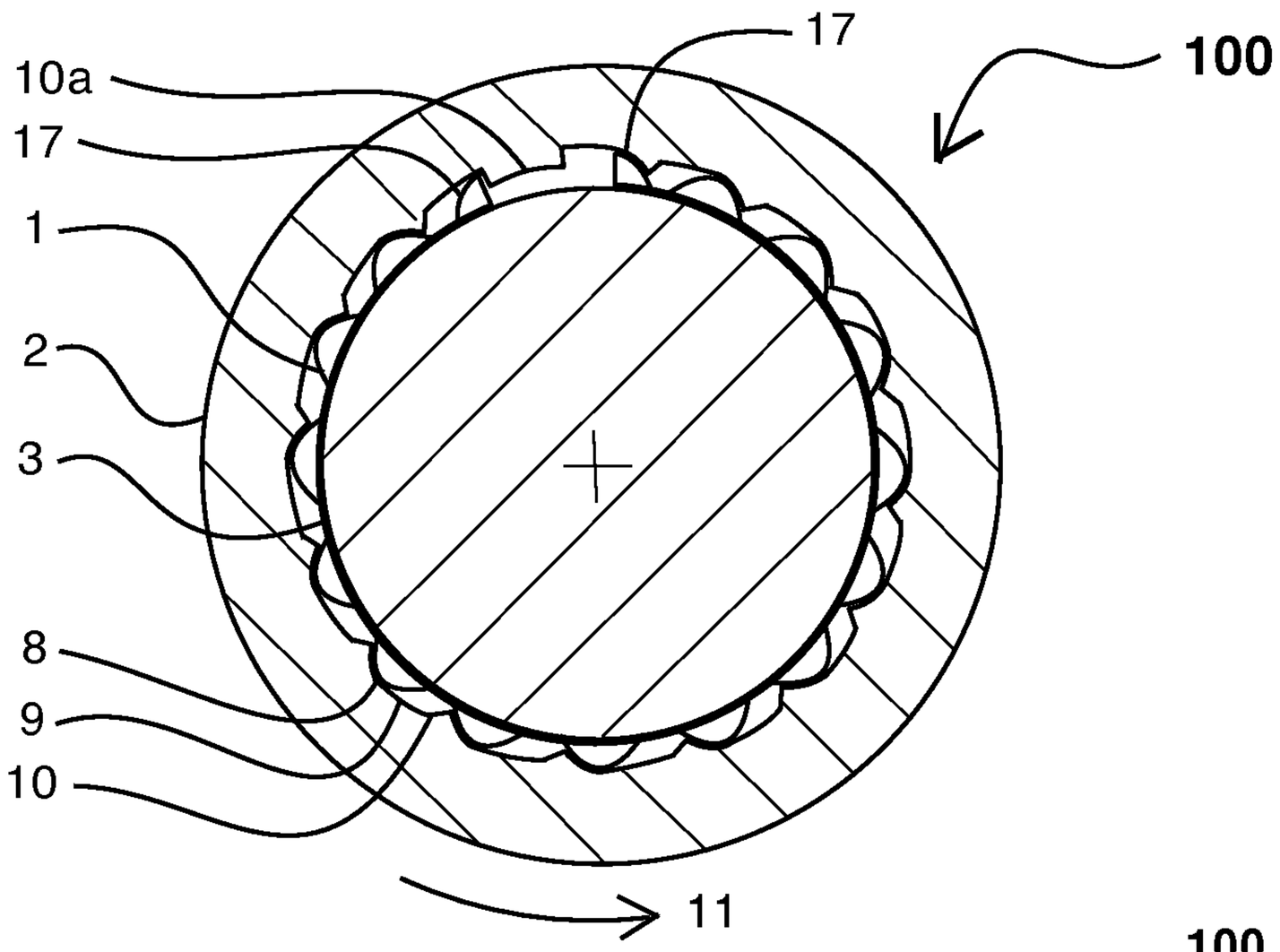


Fig. 9

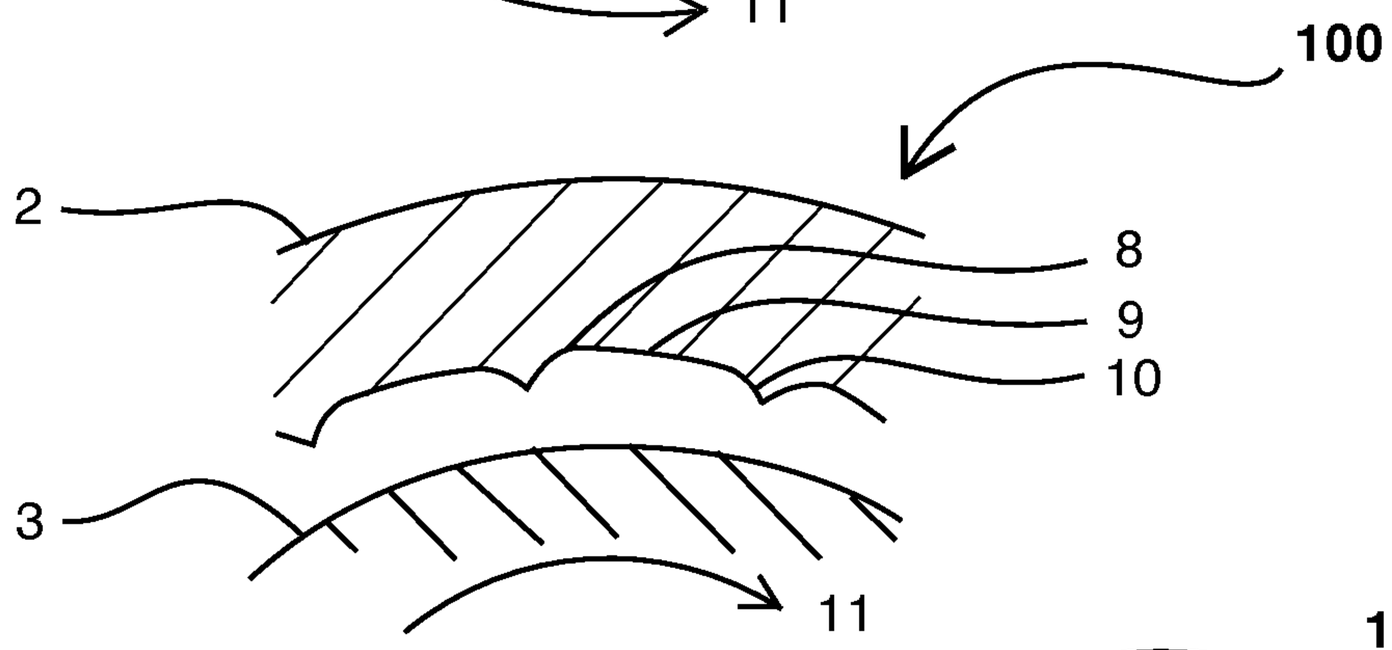


Fig. 10

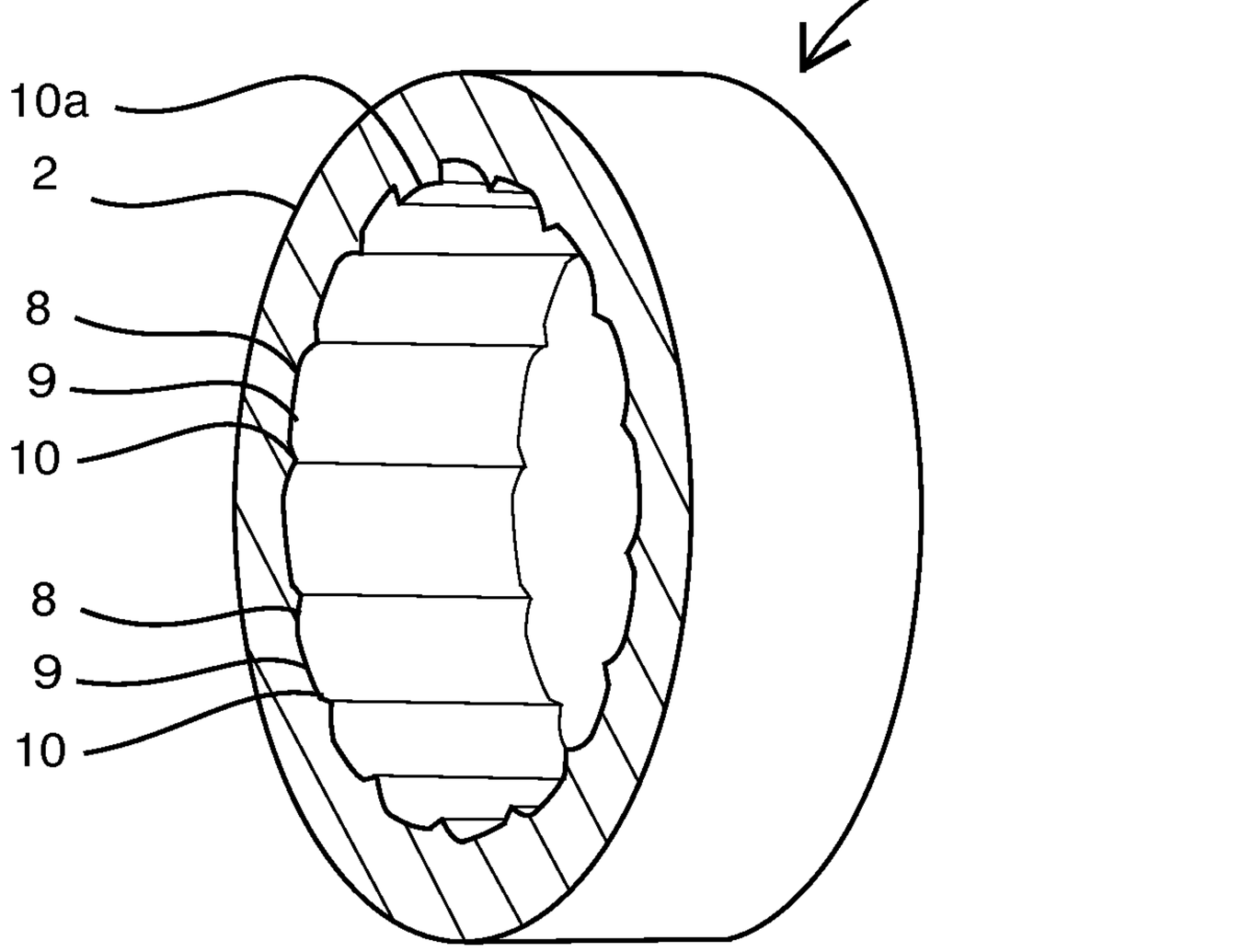


Fig. 11

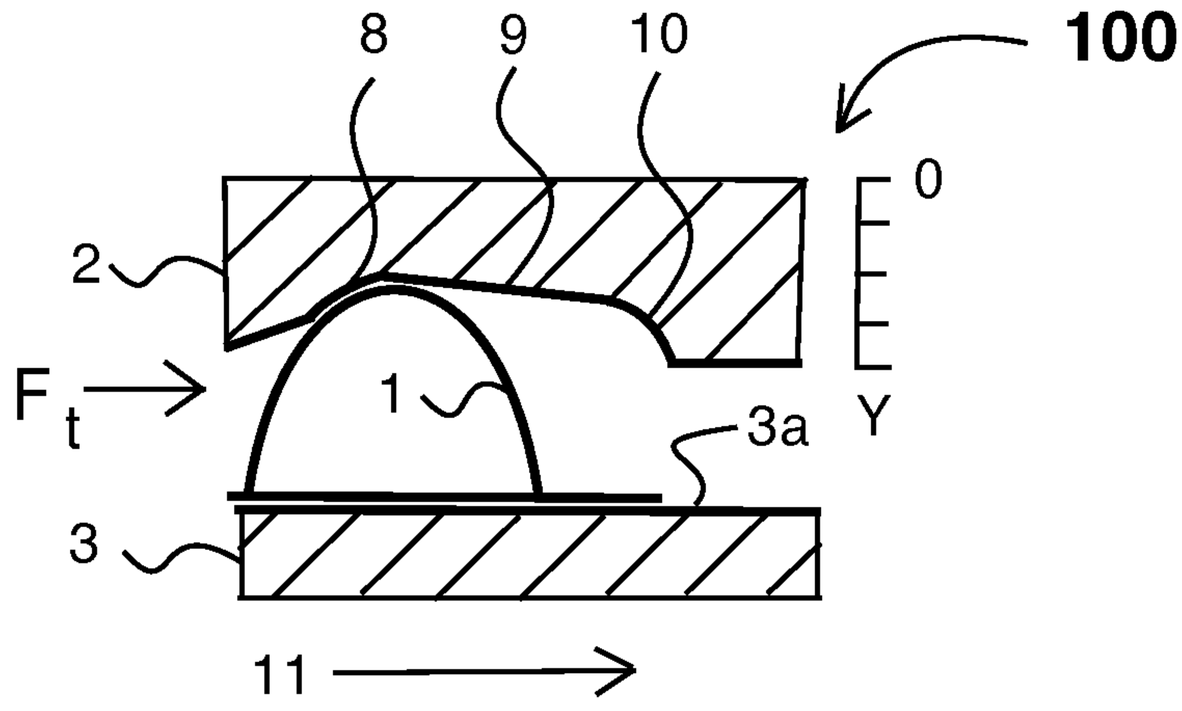


Fig. 12

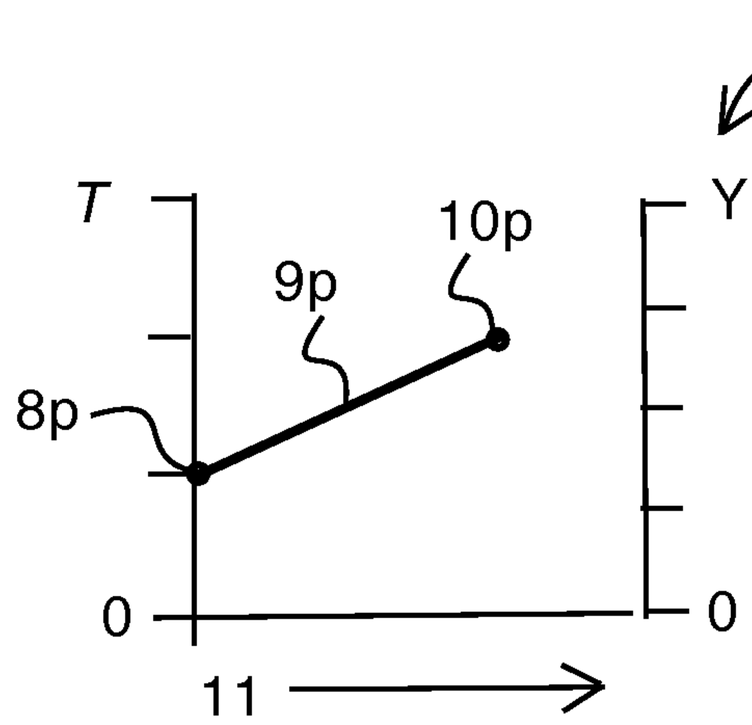


Fig. 13

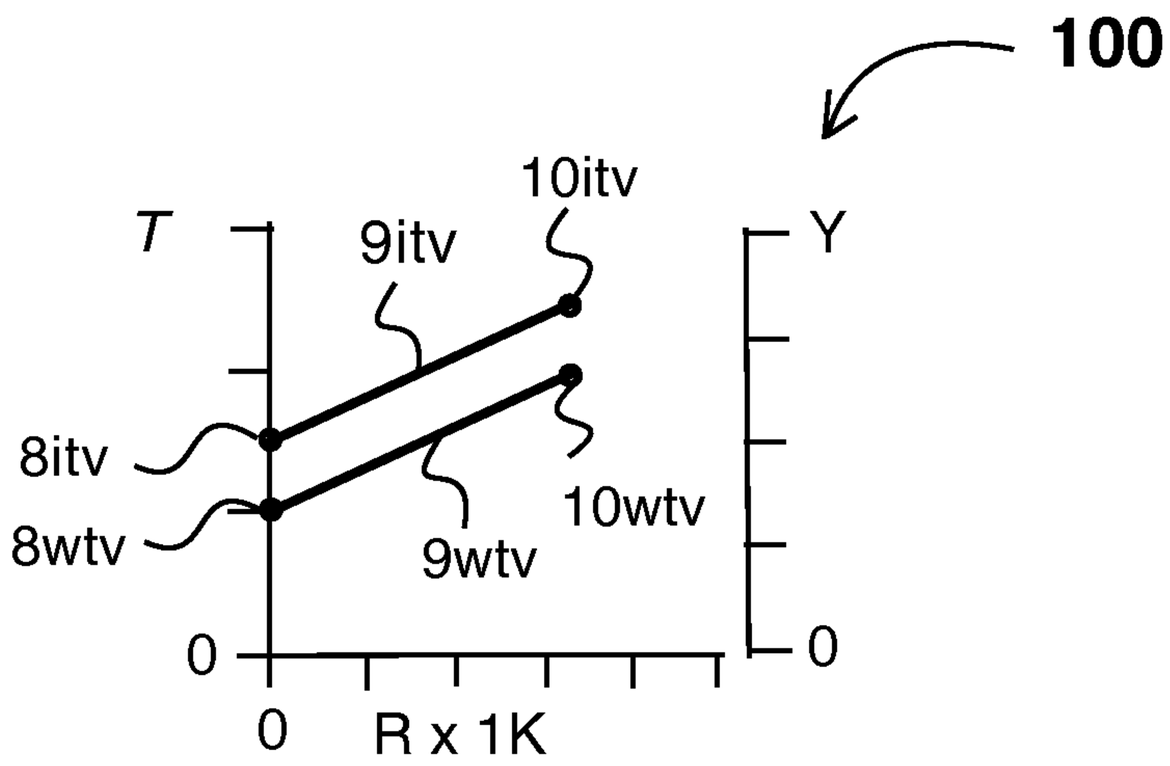


Fig. 14

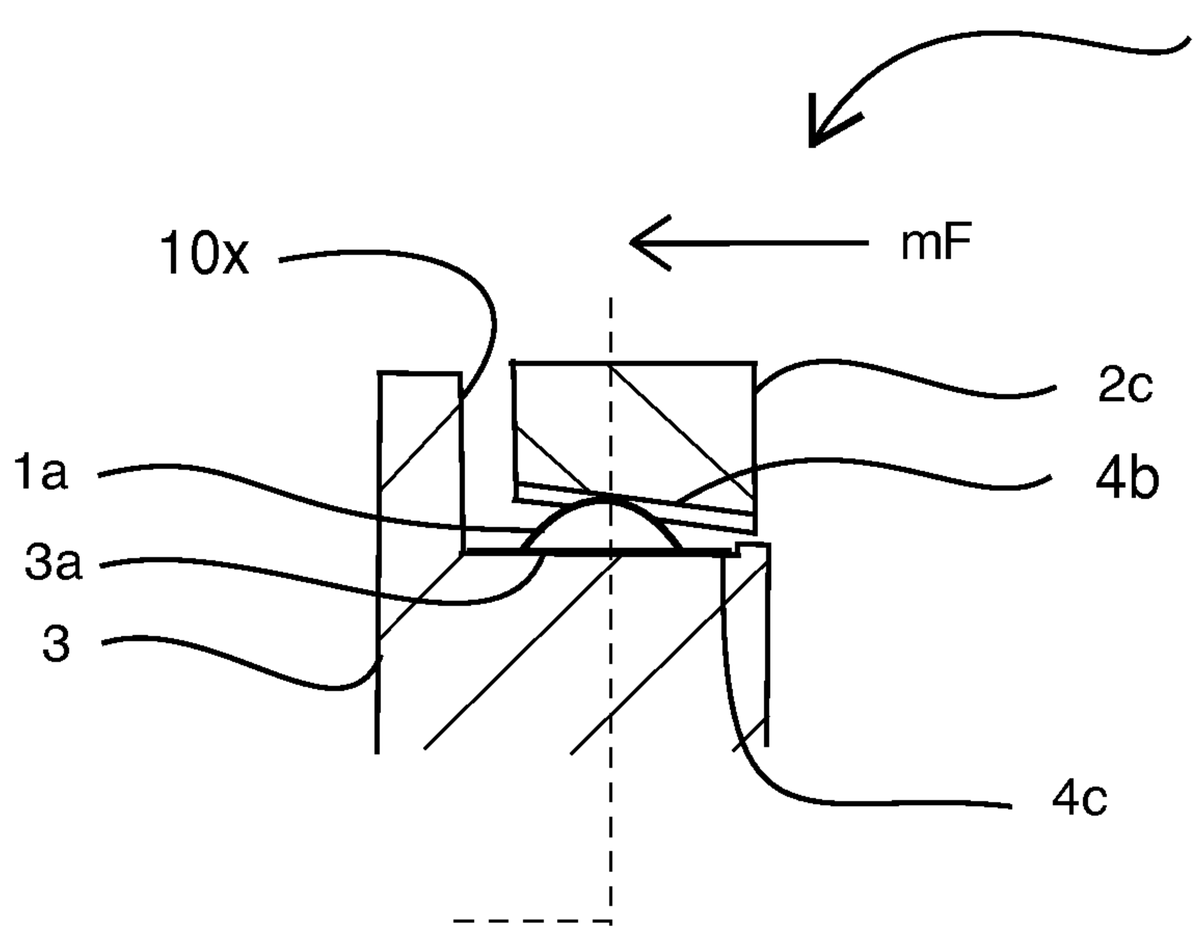


Fig. 15

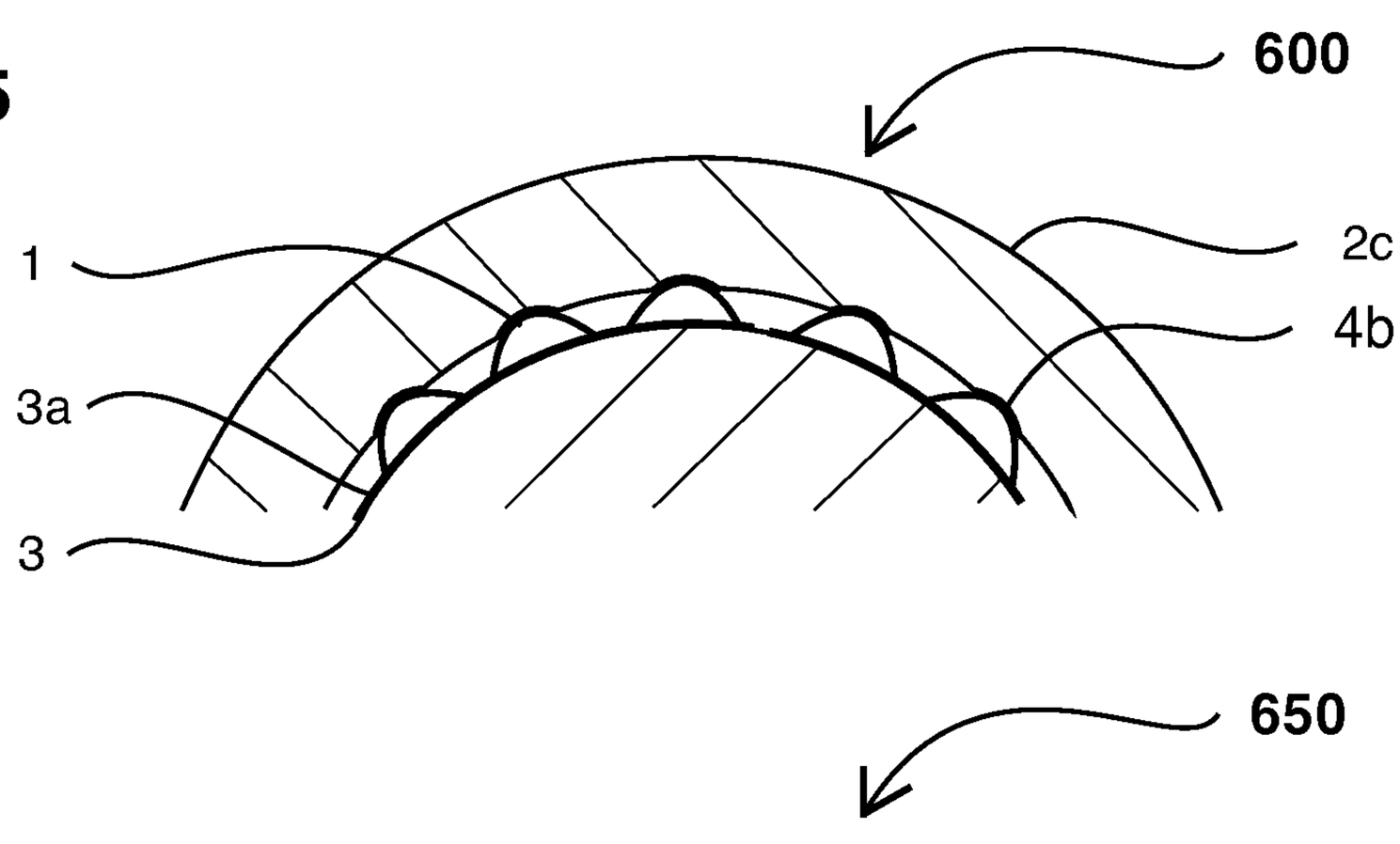


Fig. 16

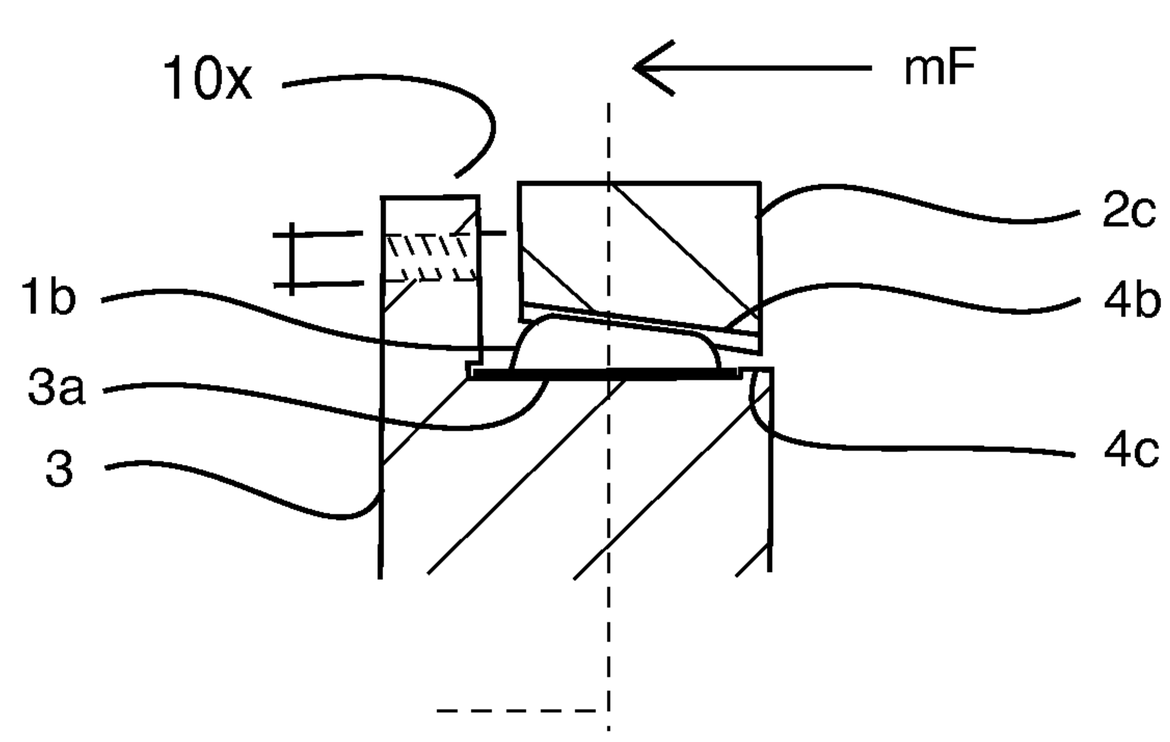


Fig. 17

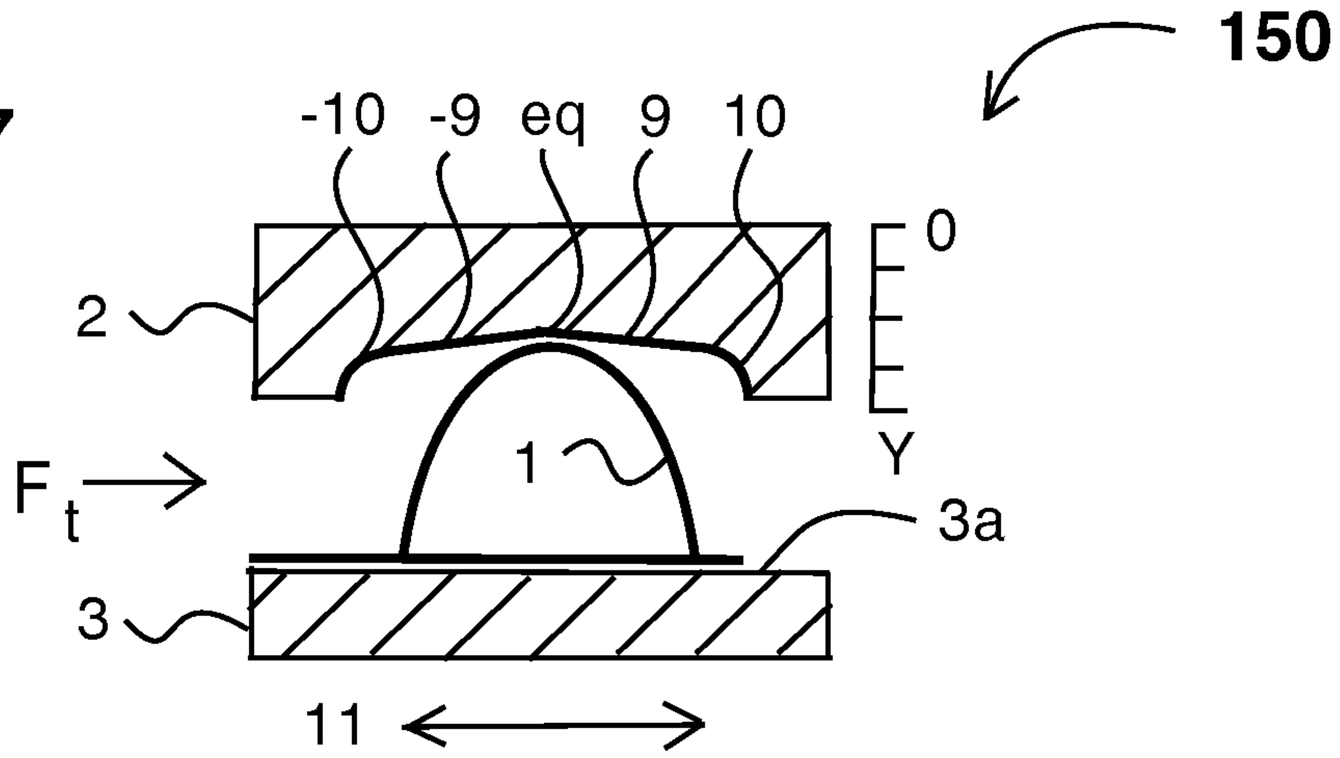


Fig. 18

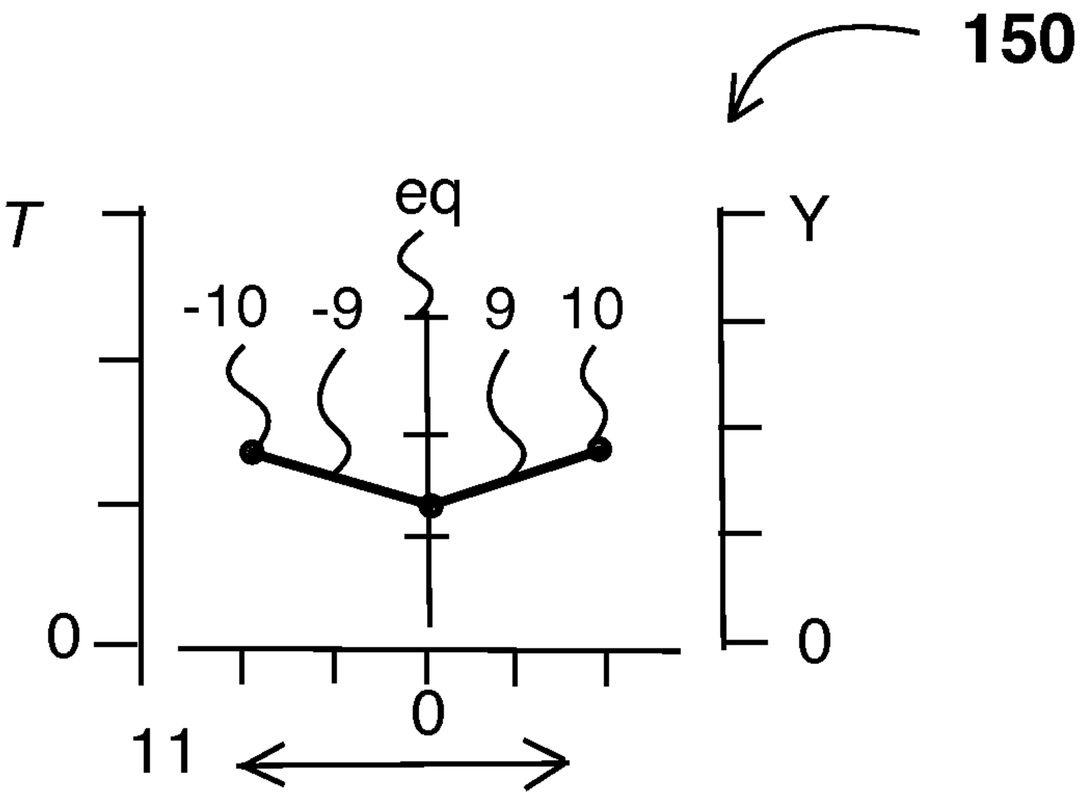


Fig. 19

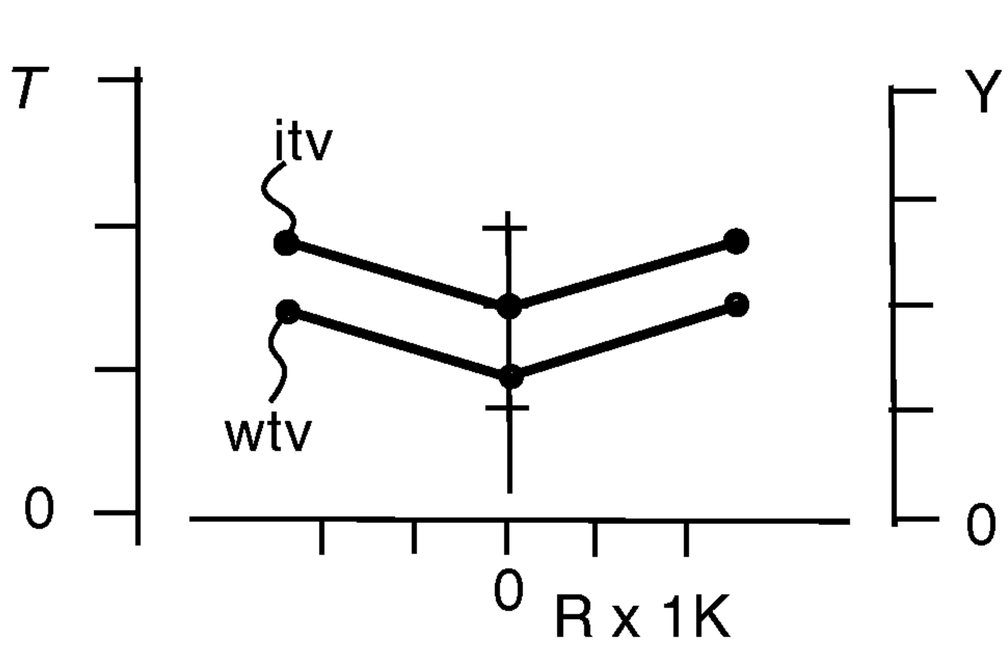
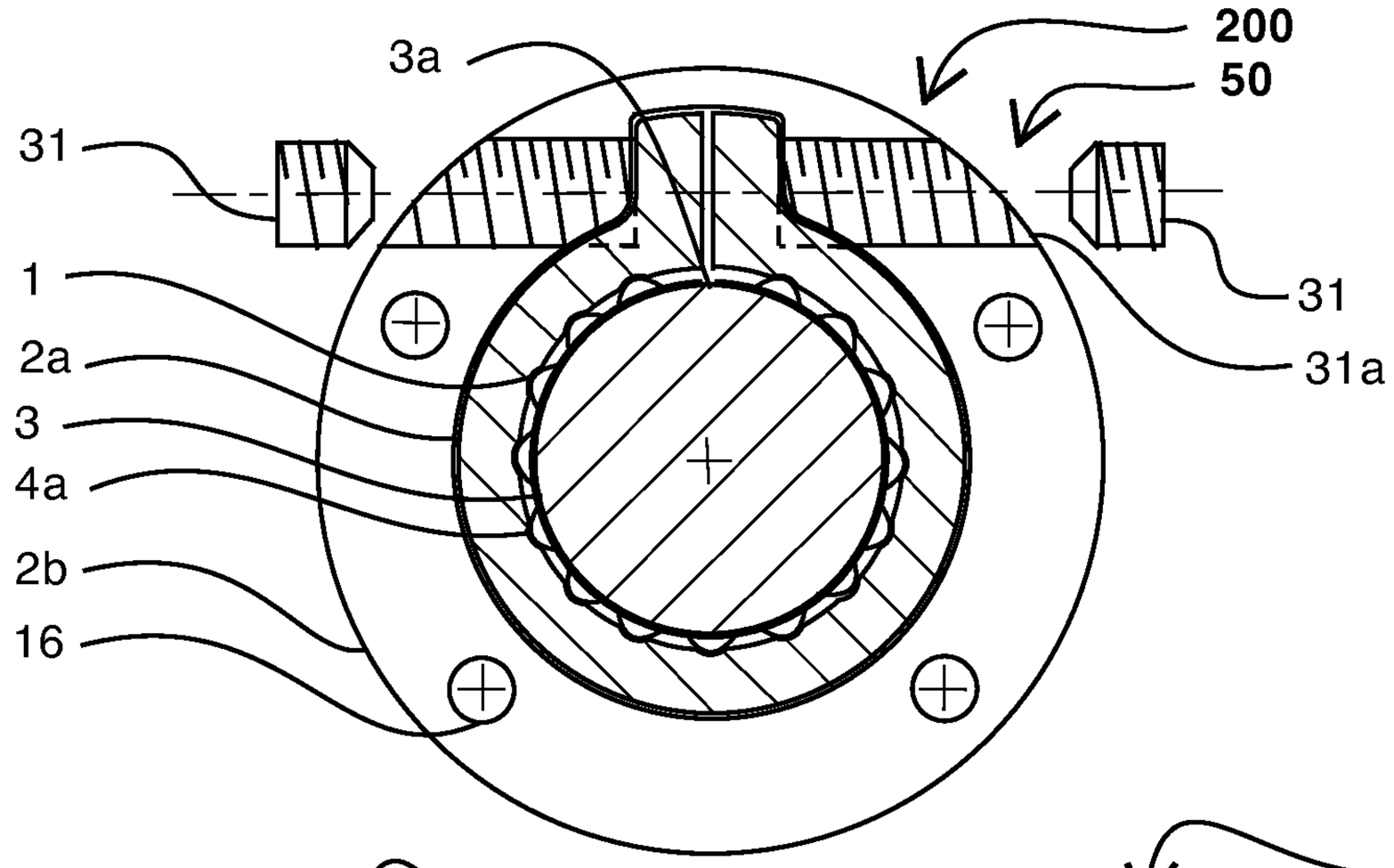


Fig. 20



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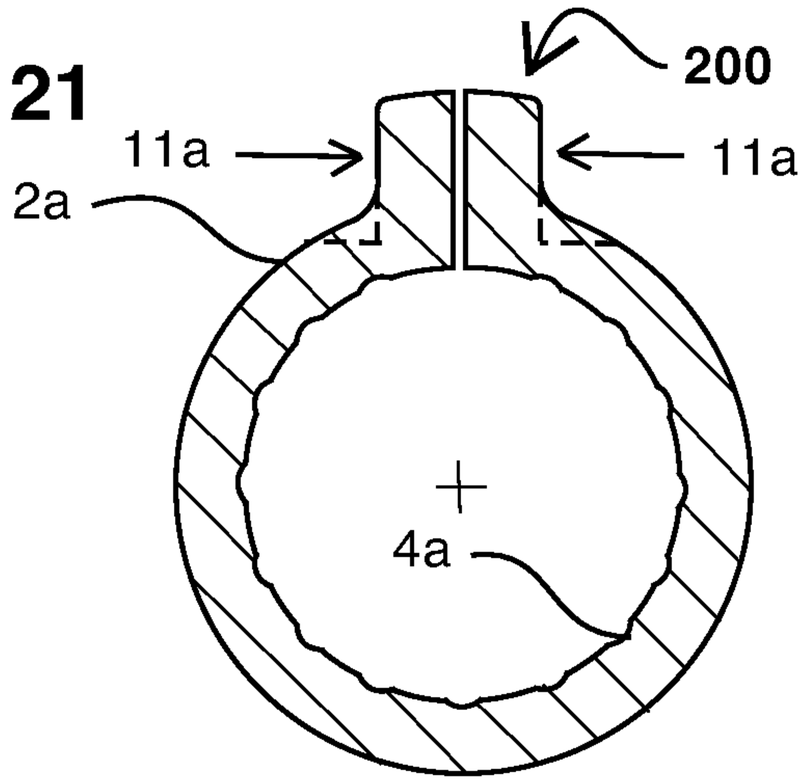


Fig. 22

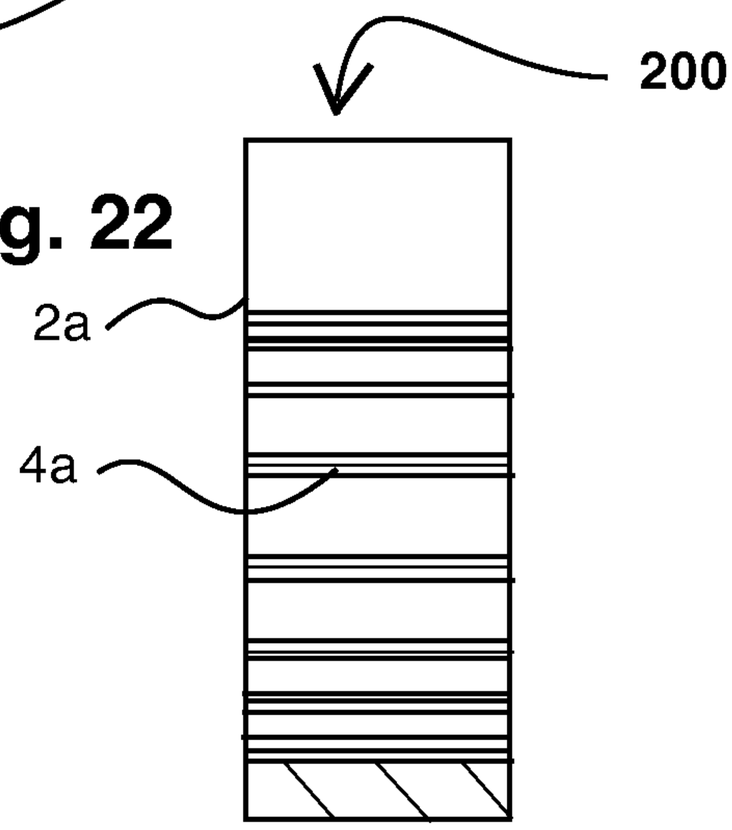


Fig. 23

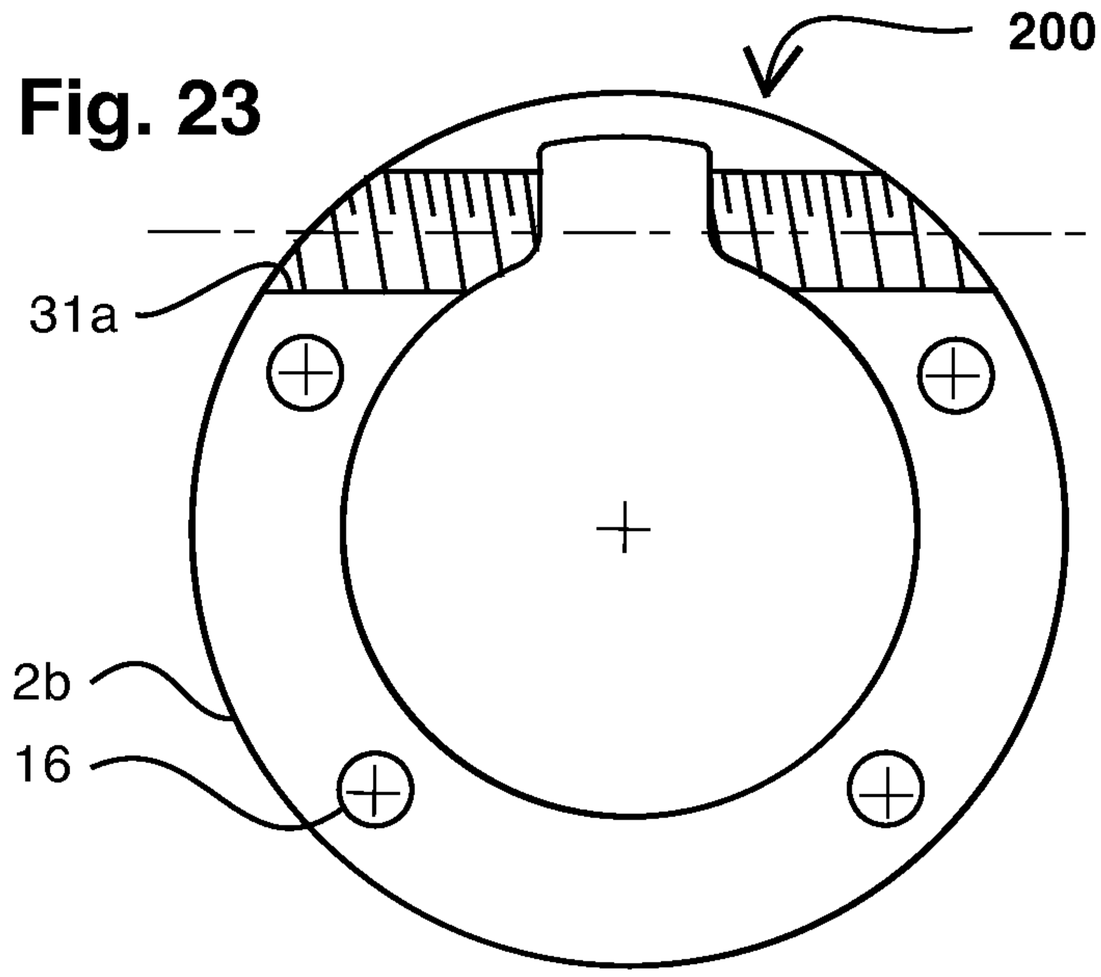


Fig. 24

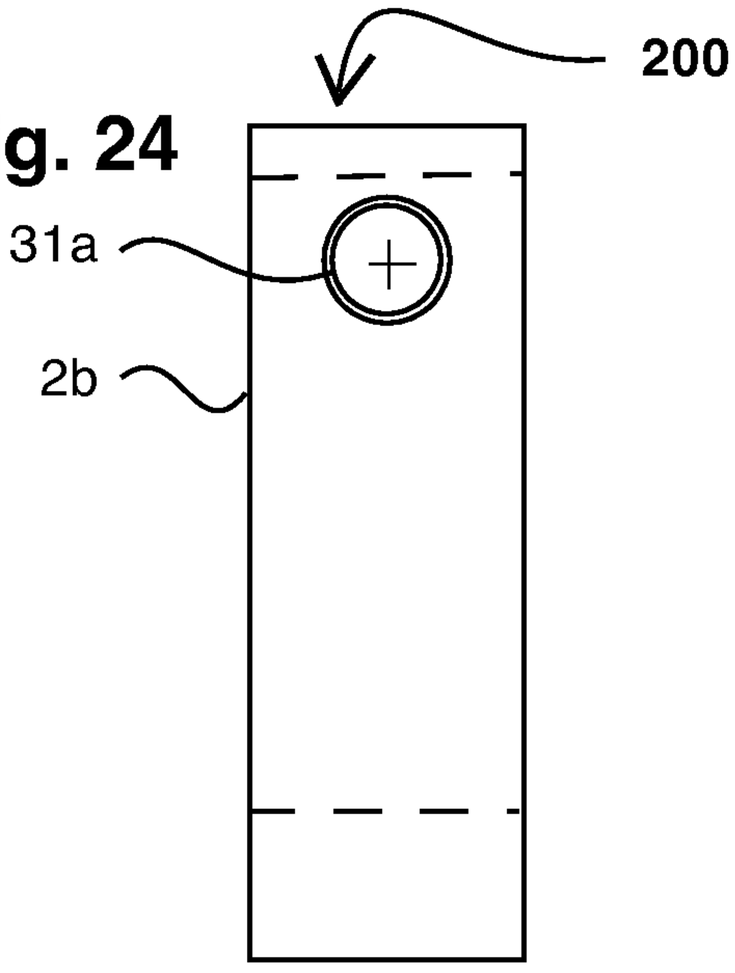


Fig. 25

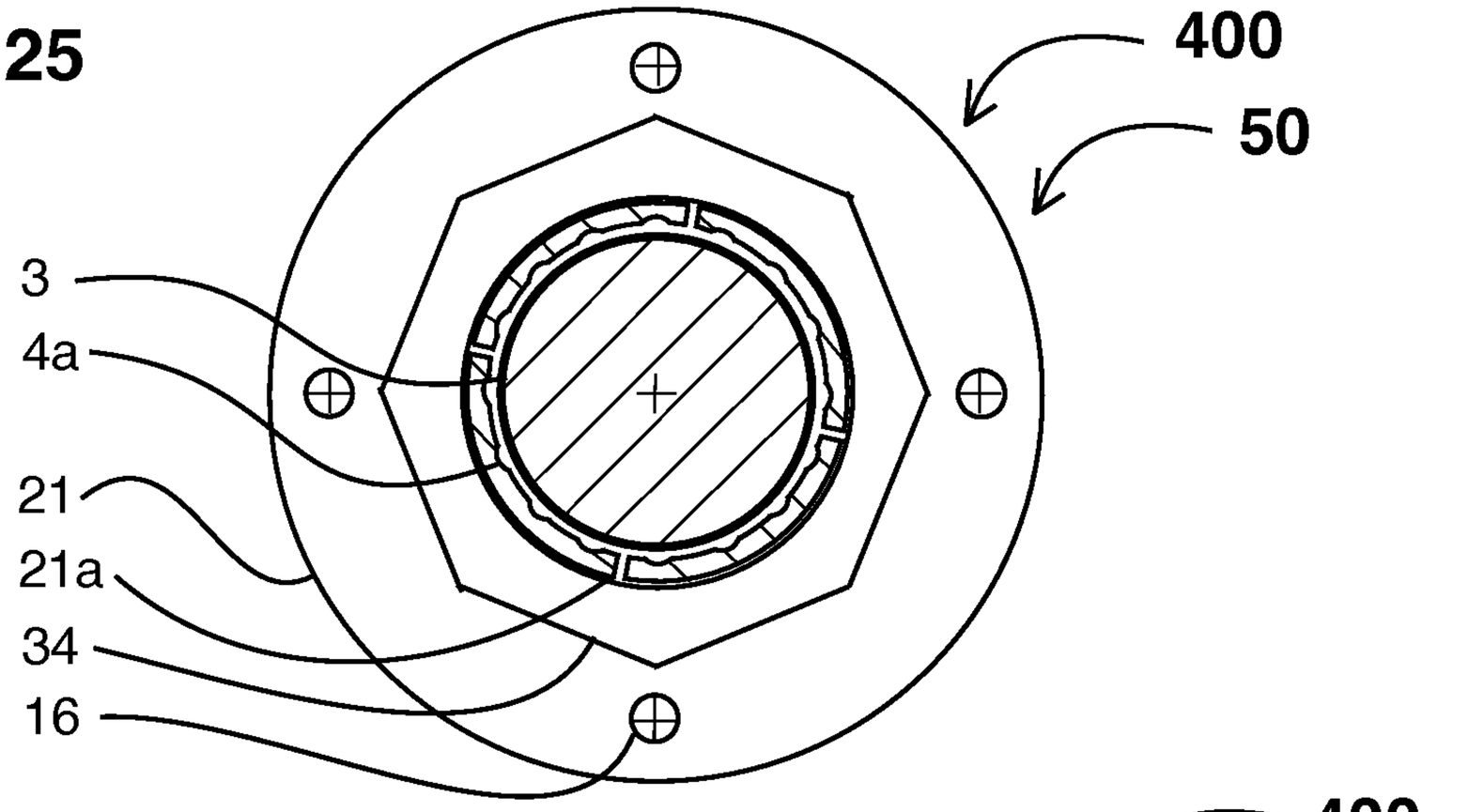


Fig. 26

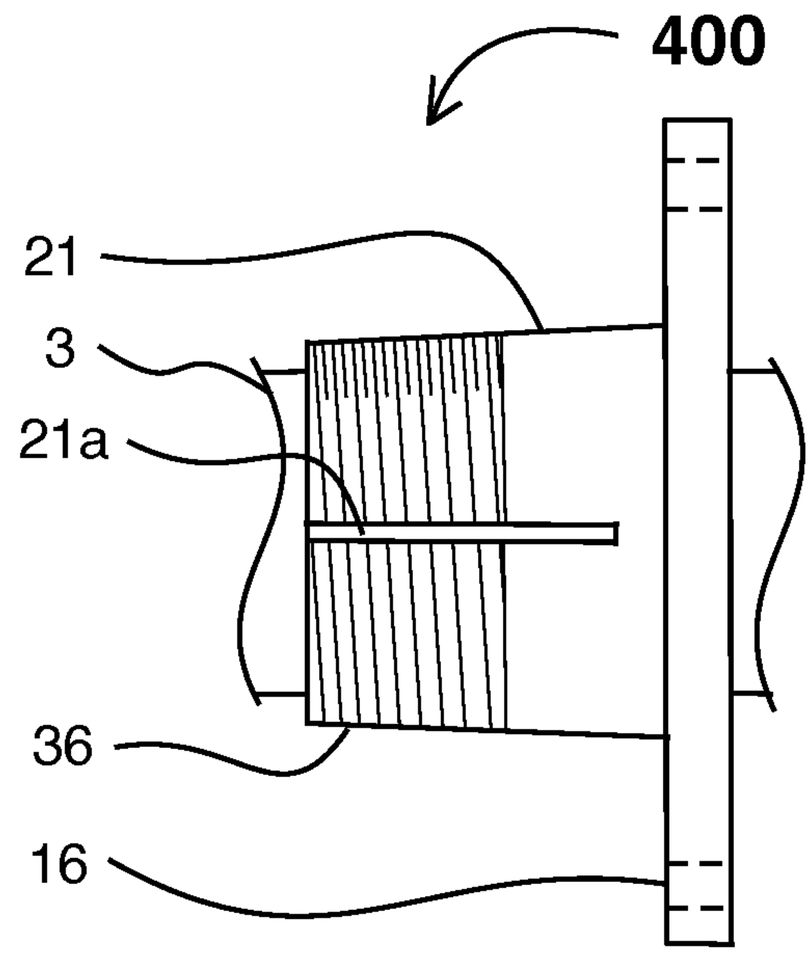


Fig. 27

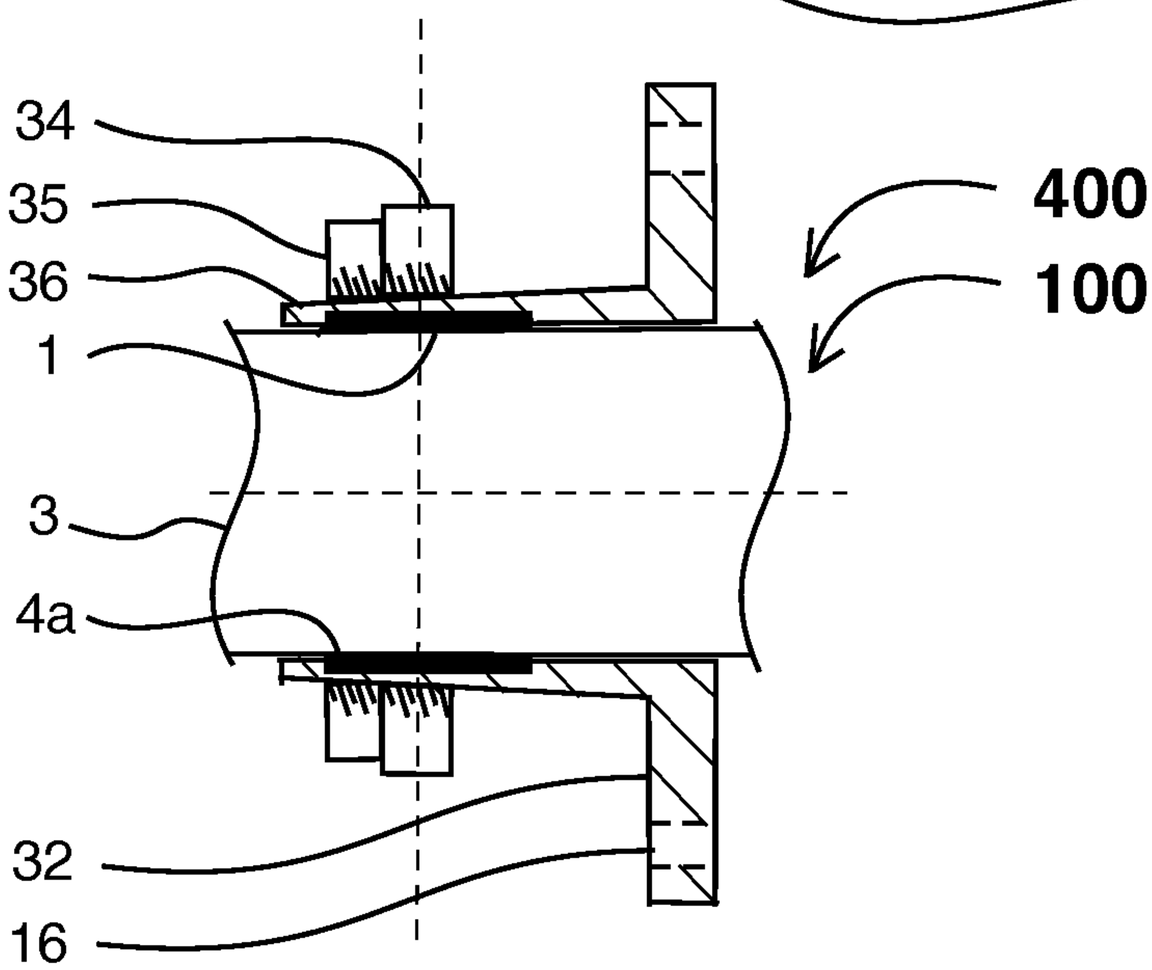
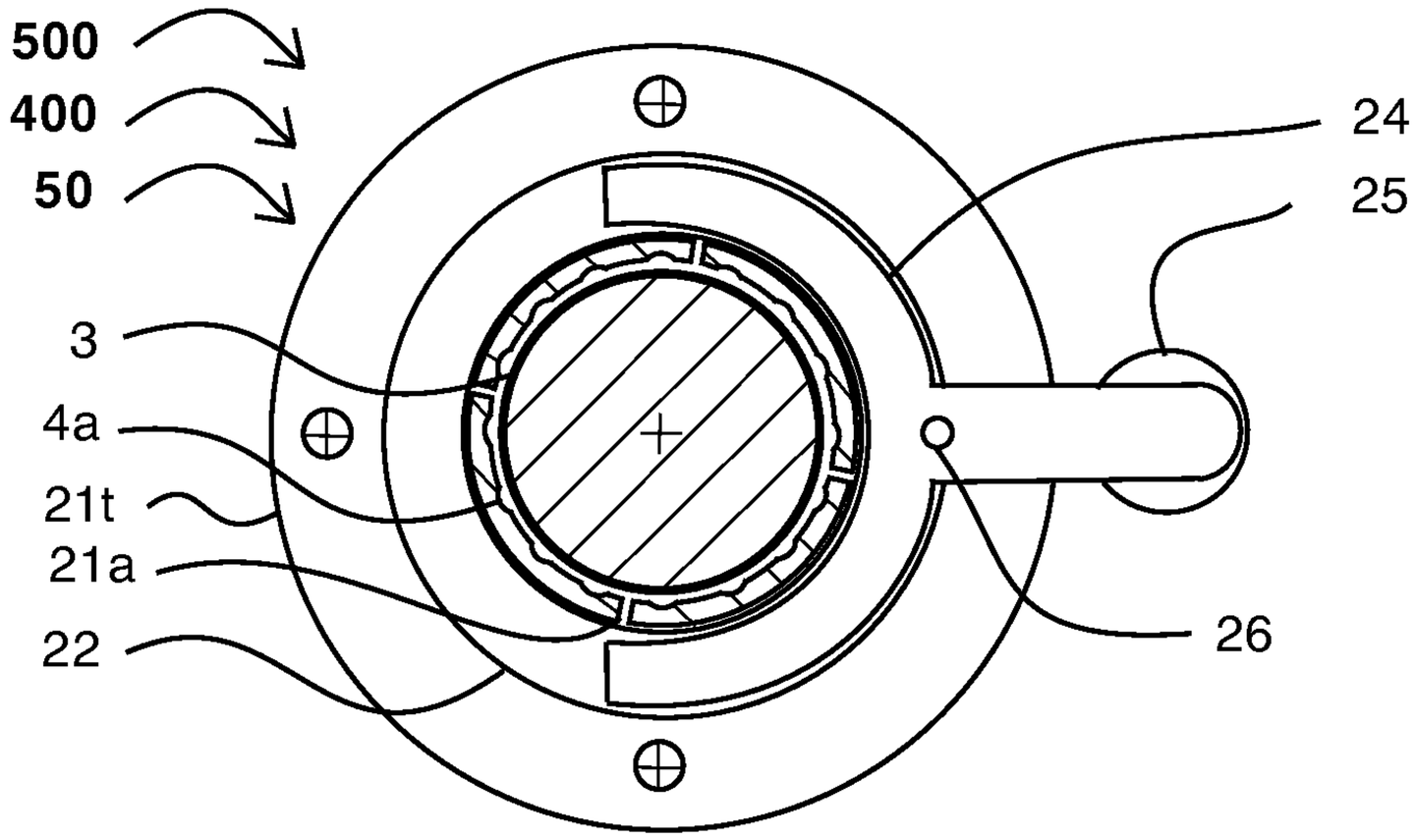


Fig. 28



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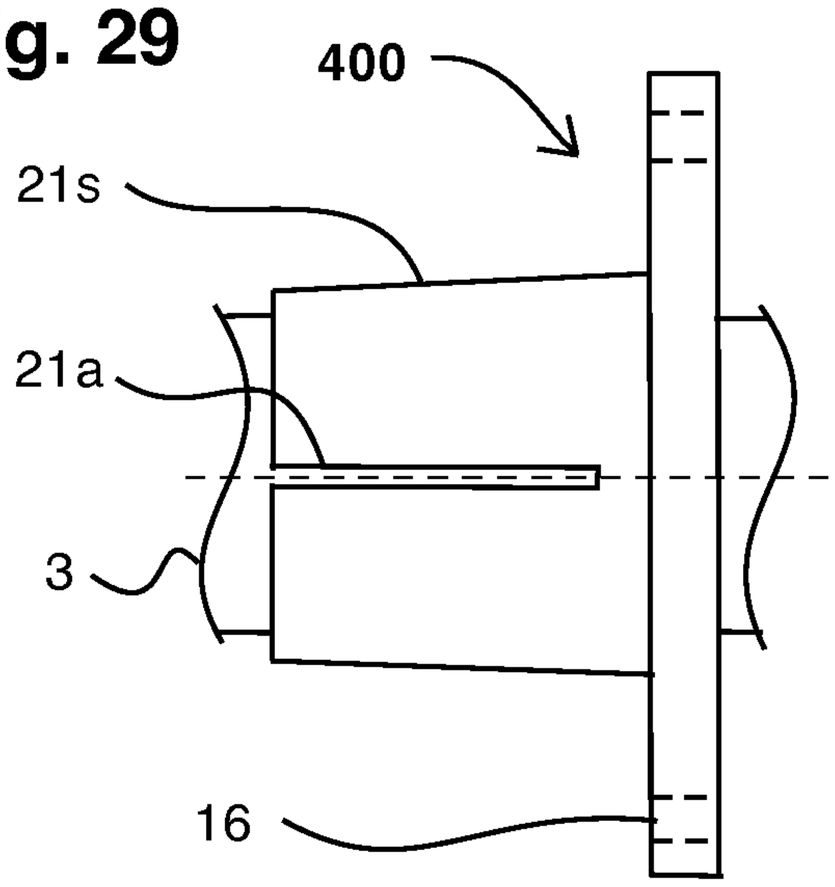

Fig. 30

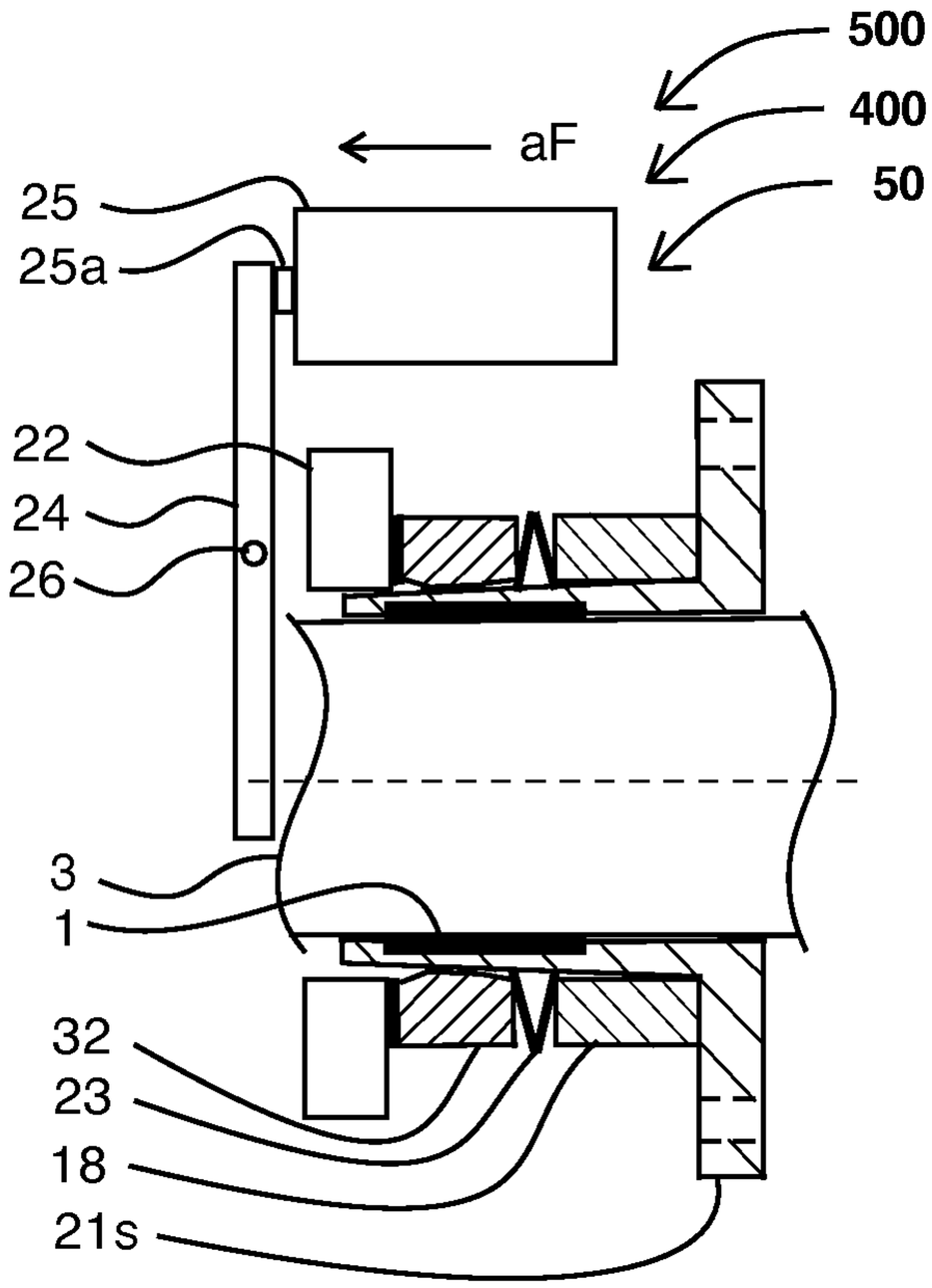

Fig. 31

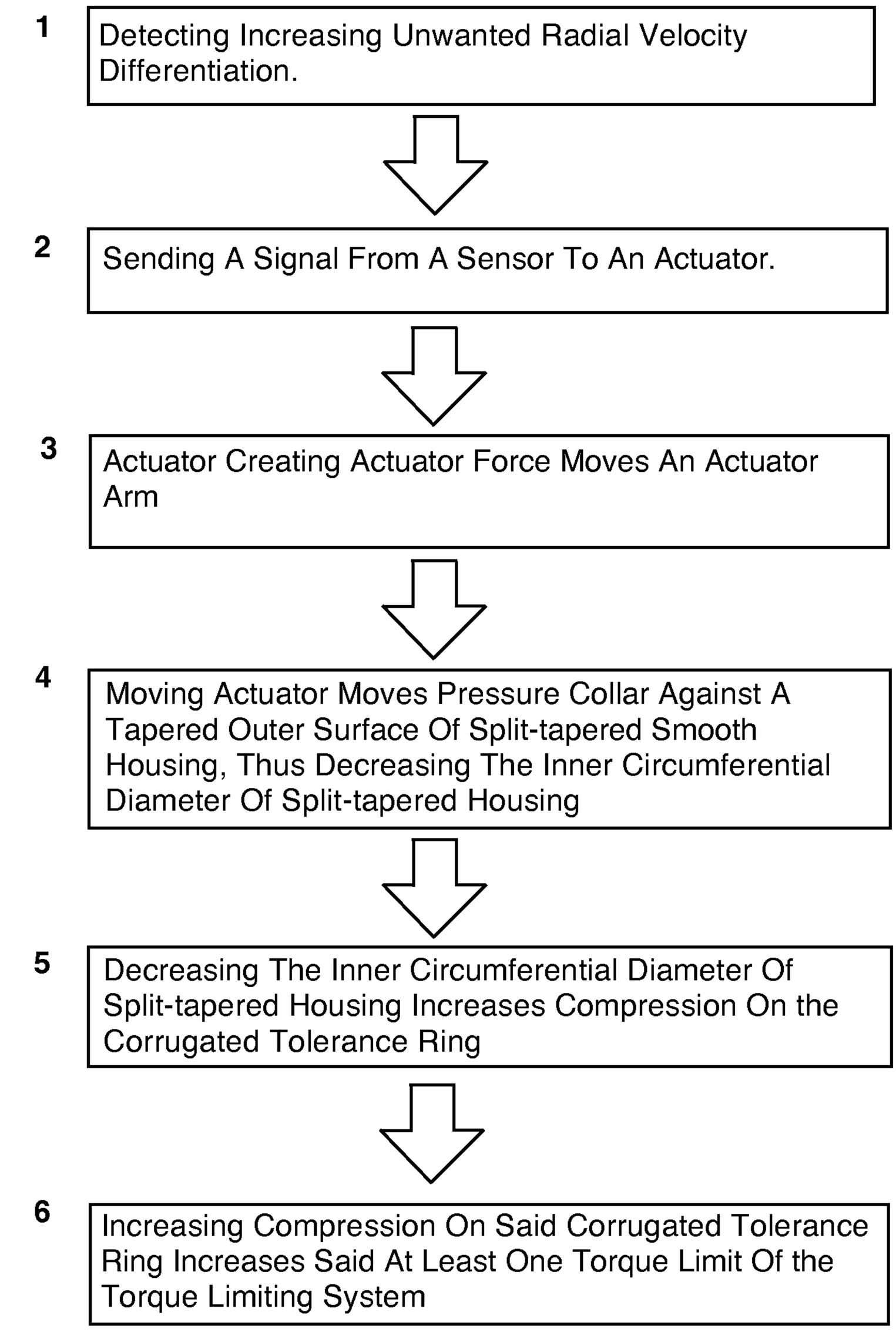
1
Detecting Increasing Unwanted Radial Velocity Differentiation.
2
Sending A Signal From A Sensor To An Actuator.
3
Actuator Creating Actuator Force Moves An Actuator Arm
4
Moving Actuator Moves Pressure Collar Against A Tapered Outer Surface Of Split-tapered Smooth Housing, Thus Decreasing The Inner Circumferential Diameter Of Split-tapered Housing
5
Decreasing The Inner Circumferential Diameter Of Split-tapered Housing Increases Compression On the Corrugated Tolerance Ring
6
Increasing Compression On Said Corrugated Tolerance Ring Increases Said At Least One Torque Limit Of the Torque Limiting System

Fig. 32

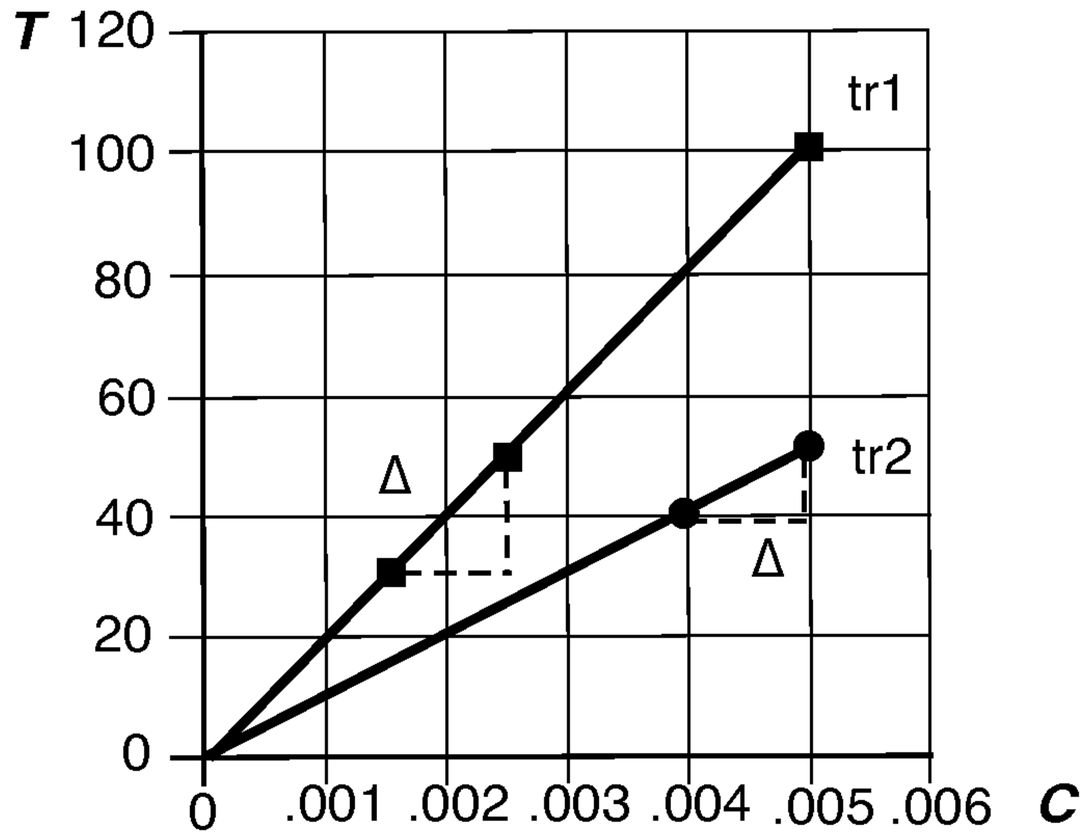

Fig. 33

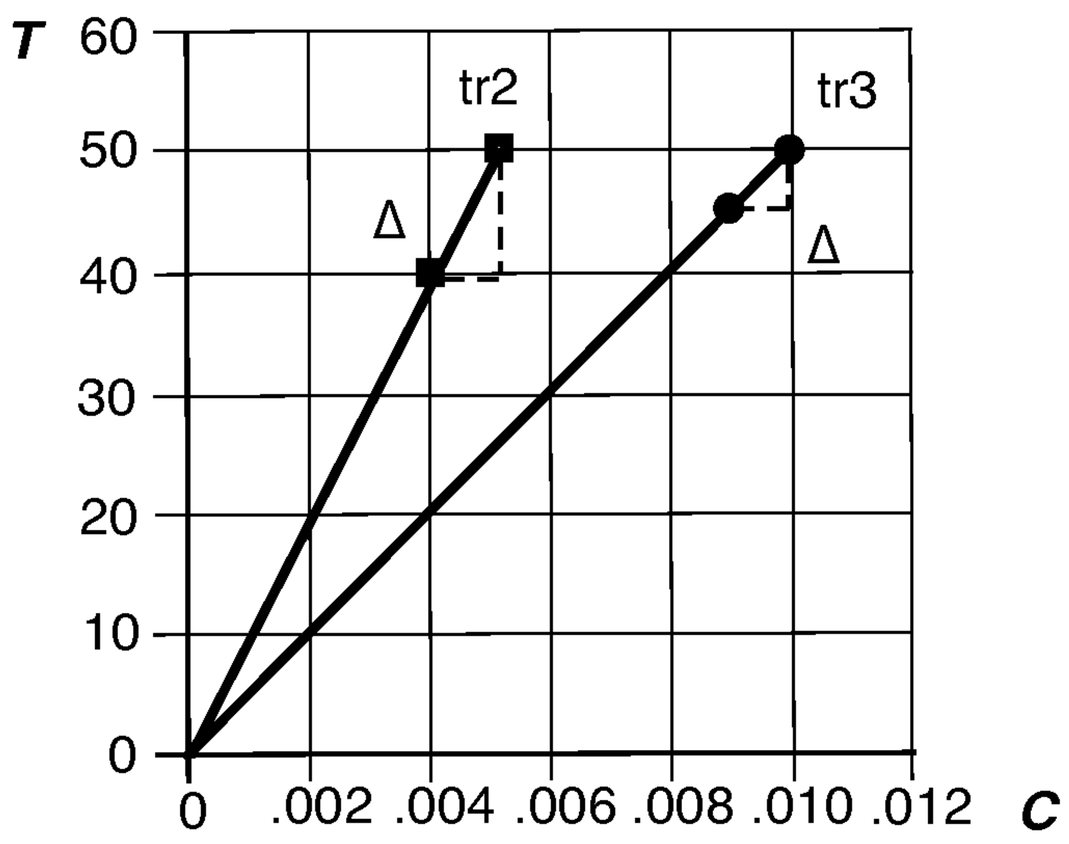

Fig. 34

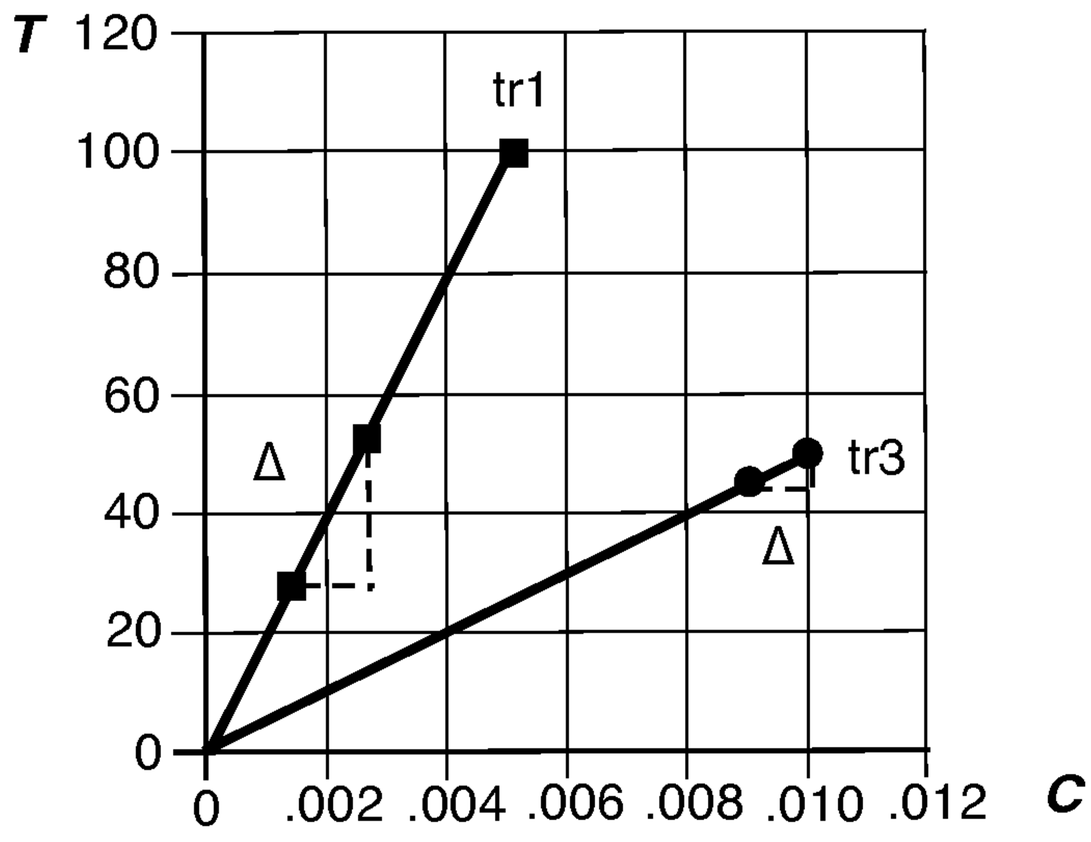

Fig. 35

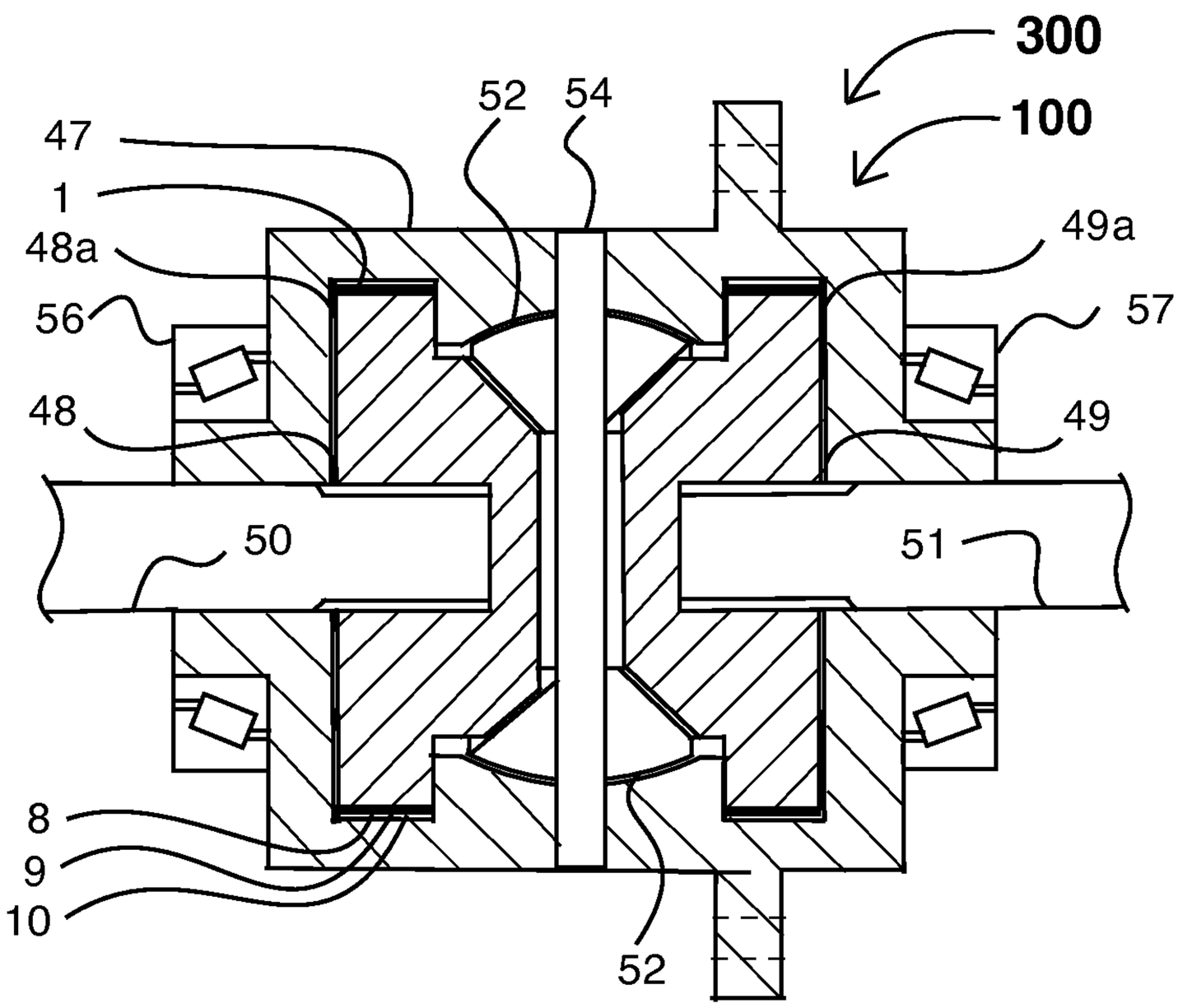
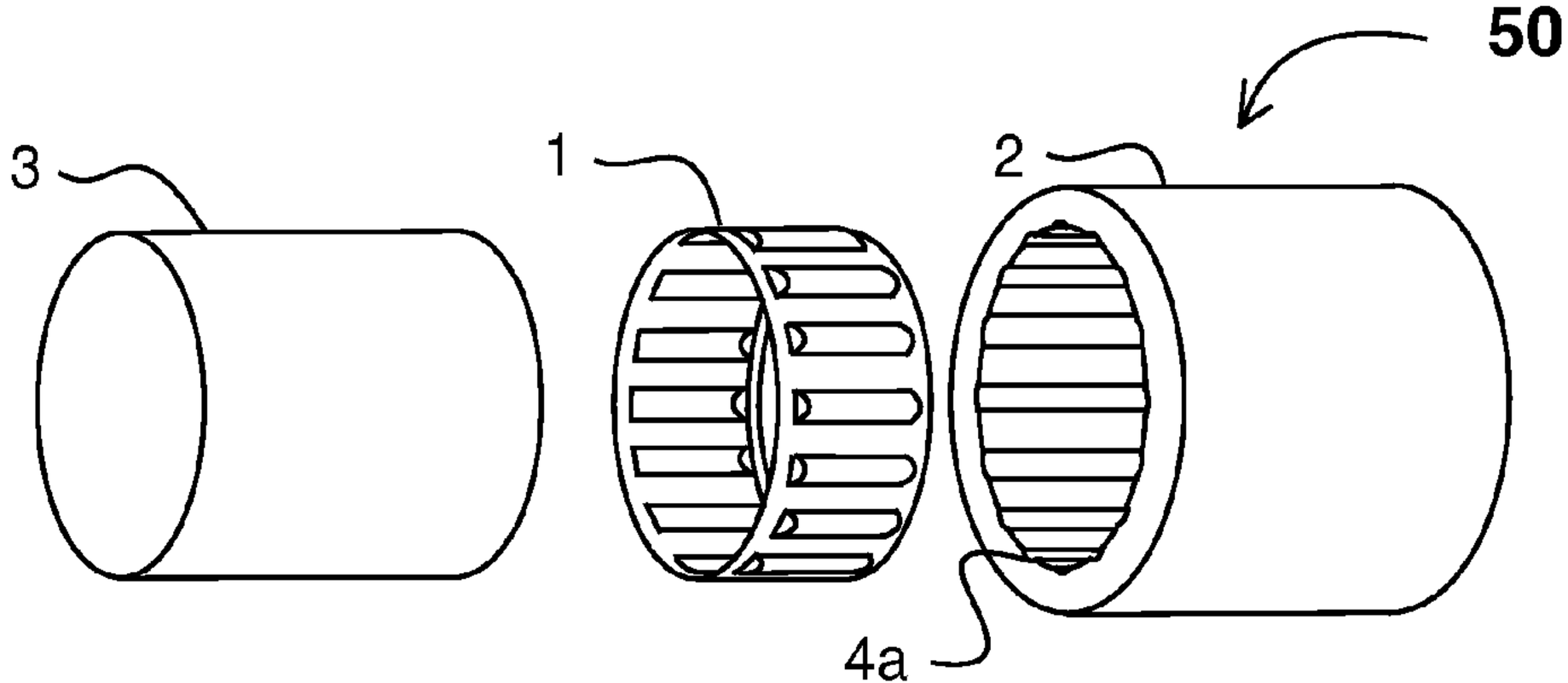
Fig. 3