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**Seat belt retractor having a torsion bar**

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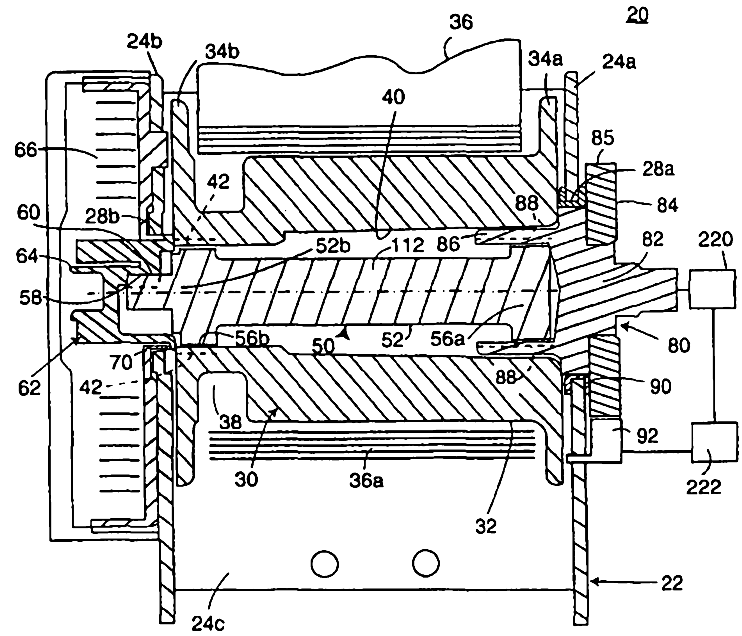
(54) Title: SEAT BELT RETRACTOR HAVING A TORSION BAR





(57) Abstract

A seat belt retractor (20) includes a frame (22) to rotationally support a torsion bar (50) and spool (30). The torsion bar is characterized by an elastic deformation zone and a sharp onset into a plastic deformation zone. The spool is operatively connected to rotate with the torsion bar. The retractor also includes a locking device (80), activated during a vehicle crash and operatively linked to the torsion bar for preventing one side of the torsion bar from rotating while permitting the other side and the spool to rotate once loaded by the vehicle occupant.

# SEAT BELT RETRACTOR HAVING A TORSION BAR

The present invention generally relates to seat belt retractors having torsion bars.

The classic type of seat belt retractor comprises a frame with a spool rotationally mounted upon the frame. The spool will typically include one or more lock wheels each having a plurality of teeth that are engaged and locked by a corresponding lock pawl. The lock pawl or lock dog is rotationally mounted to the frame and movable from a disengaged position to an engaged position with a tooth of the lock wheel. In this type of retractor once the spool is locked, further rotation of the spool is prohibited. One skilled in the art will appreciate that all forward motion of the vehicle occupant will not be stopped in this type of retractor because as the vehicle occupant loads the locked retractor, the seat belt is stressed and stretches and the seat belt slips over itself (the so called film spool effect).

However, with an energy absorbing retractor, the spool and its associated mechanisms are permitted to rotate and the seat belt is controllably permitted to protract in response to the load imparted to the seat belt by the vehicle occupant. The forward motion of the vehicle occupant is restricted by a reaction force or torque generated within the retractor and modified by the stretching seat belt. In this way the protraction of the seat belt and the forward motion of the vehicle occupant are controlled. Energy absorbing seat belt retractors often employ a deformable member such as a crushable bushing or a torsion bar. In either case, the bushing is crushed or the torsion bar twisted beyond its elastic limit into its plastic range or zone of operation to generate the desired (theoretically constant) reaction torque which acts against the torque transferred to the retractor spool via the forces imparted to the seat belt by the moving vehicle occupant.

The goal of an energy absorbing retractor is to generate a generally constant reaction force to oppose the forward motion of the vehicle occupant and to be able to generate this reaction force during the crash, that is, during the entire time that the seat belt is loaded by the vehicle occupant. In theory this can be achieved by utilizing a crush bushing or torsion bar that always operates in its constant plastic zone.

In a torsion bar, seat belt retractor, one end of the torsion bar is fixedly attached to a lock wheel and the other end is fixed to the retractor spool. During a crash the lock wheel is prevented from rotating by interposing a lock dog or lock pawl within the teeth of the lock wheel. As the seat belt is loaded by the vehicle occupant, the spool will tend to rotate in opposition to the reaction torque generated within the torsion bar, as the torsion bar is twisted. The generated reaction torque depends upon the amount that the torsion bar is rotated or twisted as well as upon the physical characteristics of the torsion bar.

More specifically, the reaction torque generated by a torsion bar will vary depending upon whether the torsion bar is in its elastic, transition or plastic zones or ranges. As mentioned, in an ideal torsion bar, the elastic range is characterized by a steep (preferably infinitely steep slope or deflection curve) and the plastic range is characterized by a perfectly constant torque deflection region having a sharp transition from the elastic region. In this ideal torsion bar and corresponding seat belt retractor, once a first end of the torsion bar is locked and the spool loaded, the torsion bar will immediately make a transition from its elastic range (see curve 100 of FIG. 1) into the plastic range of operation such that a constant reaction force is generated by the retractor as the seat belt is protracted.

Prior art torsion bars have been made using a number of different manufacturing methods. In one method, an over-sized metal bar is machined to reduce its diameter to a desired dimension. Subsequently, end formations are formed on the machined bar such as by cold rolling. The machining of the bar may produce stress risers which are typically non-uniform and the cold rolling of the machined bar, it is believed, reorients the grain structure of the metal in an undesirable manner. To make the stress distribution within the torsion bar more uniform, an annealing step is often used, which adds to the cost of the final product. However, this type of torsion bar does not achieve the objects of the present invention as it displays the characteristic torque deflection curve similar to that shown in curve 102 of FIG. 1 having an elastic zone, an extended elastic/plastic transition zone and a plastic zone. In another method of manufacture the torsion bar is made using a cold-formed process in which a metal bar or wire (large diameter), has a diameter less than the desired dimension. The smaller than desired diameter bar is expanded into a bar having the desired larger diameter. This type of bar has been tested and it displays or shows a characteristic torque deflection curve similar to that of curve 102 of FIG. 1. The prior art has also suggested a method of making a torsion bar having a shortened or abrupt elastic/elastic transition zone. In this method a premachined or performed torsion bar is work hardened (by being pre-torqued or twisted beyond its yield torque level) prior to installation within a seat belt retractor. One potential deficiency of this technique is that the pre-twisting reduces the useful range through which the torsion bar can be additionally twisted, during a crash, once installed within a retractor.

There has been previously proposed another methodology of making a torsion bar for use within a seat belt retractor. The torsion bar was formed of a ductile, elongated body, located between the end formations and formed by pre-stressing bar stock by extruding an oversized metal bar into a bar of a reduced diameter with its grain structure in the vicinity of a center of the bar oriented in a longitudinal direction. The end formations of the torsion bar were formed by a cold heading process. In this process the cold headed bar was not annealed. In this process, the cold heading did not disturb the longitudinal direction of the grain structure in the central portion of the torsion bar.

It is an object of the invention to substantially overcome or at least ameliorate one or more of the above prior art disadvantages.

Accordingly, in a first aspect, the present invention provides a seat belt retractor comprising:

a spool and a torsion bar, the torsion bar including first and second end formations, the first one of the end formations is connected to the spool; the torsion bar further comprises a ductile, elongated body, located between the end formations and formed by extruding an oversized metal bar into a bar of a reduced diameter with its grain structure in a vicinity of a center of the bar oriented in a longitudinal direction, the bar being annealed and twisted to establish a determinable work.

In a second aspect, the present invention provides a seat belt retractor comprising:

a frame;

a torsion bar comprising an extruded, reduced diameter center portion rotationally supported relative to the frame for generating a predetermined reaction torque as it is twisted, the torsion bar characterised by an elastic deformation zone and a sharp onset onto a plastic deformation zone;

a spool operatively connected to rotate with the torsion bar;

a lock means, adaptable during a vehicle crash and operatively connected to a first portion of the torsion bar for, at least temporarily stopping the torsion bar and the spool from rotating;

the spool having a seat belt positioned thereon, wherein with the lock means activated to prevent the first portion of the torsion bar from rotating and with a load applied to the seat belt, the spool and the torsion bar are rotatable in a direction of seat belt protraction opposed by the reaction force generated by the torsion bar as it twists.

In a third aspect, the present invention provides a seat belt retractor comprising:

a spool having a determinable amount of seat belt stored thereon and a torsion bar, the torsion bar including first and second end formations, the first one of the end formations is drivingly connected to the spool;

the torsion bar further includes a ductile, elongated body, located between the end formations and formed by extruding an oversized metal bar into a bar of a reduced diameter with its grain structure in the vicinity of a center of the bar oriented in a longitudinal direction, the bar being annealed and twisted to establish a determinable work, the retractor generating a reaction force on the belt to oppose forward motion of an vehicle occupant in a crash, the reaction force being generally constant over a period of time as the seat belt protracts from the spool.

Particularly, it has been found that if the bar stock is first extruded, with the formations cold headed as first proposed but subsequently if the torsion bar is annealed but not at a temperature or duration which will not cause the grain structure to increase and the torsion bar is pretwisted, excellent results can be expected.

Brief Description of the Drawings

FIG. 1 shows a torque-deflection curve for an idealized torsion bar and for a conventional torsion bar having a circular cross section.

FIG. 2 shows test data illustrating a torque-deflection curve for a torsion bar that has been cold-formed and annealed.

FIG. 2a shows test data for a torsion bar that has been cold formed, annealed and pretwisted.

FIGS. 3a and 3b show a torsion bar in various steps of completion.

FIGS. 4a and 4b are end plan views of the torsion bar.

FIG. 5 shows a seat belt retractor incorporating a torsion bar of the present invention.

FIG. 6 shows a curve of belt force versus time.

## Detailed Description of the Invention

FIGS. 3a and 3b show a torsion bar made in accordance with the present invention. The torsion bar 50 includes a center body 52 and two end formations 52a, 52b which enable the torsion bar to be respectively mated with a spring arbor and a ratchet body. The torsion bar 50 is made from a bar (or large diameter wire) of metal having a circular diameter. In the preferred embodiment the bar or wire is made from AIAI/SAE 1005 Modified (CHQ) grade wire or stock. The wire or stock is formed using a known hot rolled, aluminum killed fine grain spheridized annealed steel with a Rockwell B rating of between 50 and 70 and preferably in the range of 60 - 65. This metal should have a surface finish of 0.1mm maximum seam depth. The tensile strength should be between 2,812 and 4,218 kilograms per square centimeter. The maximum chemical constituents of the bar stock are preferably: Carbon 0.06, Manganese 0.35, Phosphorous 0.02, Sulfur 0.02, Silicon 0.1, Copper 0.01, Chromium 0.08, Molybdenum 0.04 and Aluminum 0.06. The elongation is 25% at 5 centimeters. The maximum grain size is 5. The diameter of the bar stock is between 9.525 and 11.099 mm. This metal is chosen because it is sufficiently ductile with its grain structure generally longitudinally oriented.

The initial diameter Di (see FIG. 3a) of the metal bar 110 is approximately five percent (5%) greater than the desired or final diameter Dd of the torsion bar 50. The final diameter of the torsion bar is about 1cm (9.8mm). The final diameter of the torsion bar is achieved using a cold forming extrusion process in which the bar 110 (see FIG. 3a) is partially forced through a die (not shown) and then bar 110 is cut to the desired length. During this extrusion process or step, the grain structure of the metal bar 110 remains oriented in a generally longitudinal direction. Reference character 53 identifies a schematic illustration of a typical pattern of a longitudinal grain structure. That is, the grain structure is oriented substantially parallel to the axis 112 of the torsion bar 50. Even if the grain structure of the original bar or wire stock does not have its grain structure longitudinally oriented this extrusion process will so orient the grain structure.

Subsequent to reducing the diameter of the bar 110 to the desired dimension, the ends of the bar are cold headed to form the end formations 52a, 52b. These formations can be formed in a multi-step process or in a single step. FIGS. 4a and 4b show end views of each of the end formations. The end formation 52a includes an enlarged diameter section upon which is formed a plurality of splines 56a. The end formation 52b includes an enlarged section having splines 56 and at least one integrally formed notch or groove 58 which provides a means to receive a spring arbor 60 as shown in FIG. 5. The cold headed process used to form the enlarged diameter splined sections 56a, 56b will maintain the longitudinal grain structure in the bar as well as add a radial component to the grain structure of the material. However, it is believed the transition radii 55, 57 (see FIG. 3b) prevent any discontinuities in the grain structure and stress distribution. Subsequently, the above-formed torsion bar is annealed at a temperature and duration that does not disturb the grain size of the bar.

Unfortunately, the annealed torsion bar does not provide the precise torque-deflection curve that is desired. Characteristically, this curve (see the test data of FIG. 2) exhibits a low yield point. The real-world consequence of this low yield point is that the annealed torsion bar may yield prematurely.

Subsequent to annealing the torsion bar is again pre-stressed by twisting. For the above described bar material (formed into a circular bar of 9.8 mm diameter torsion bar) and overall length of 58.3 mm (from tip-to-tip of the end formations) the bar is twisted 0.5 revolution. The resulting test data is shown in FIG. 2a. As can be seen the low yield point exhibited in FIG. 2 has been eliminated. The torque generated by the bar in its plastic regions increases somewhat linearly at about a slope of 0.0067 Nm per degree. Subsequent testing of this torsion bar has confirmed that the effect of removing the low yield point improves the kinematic performance in a crash. Reference is again made to the test data illustrated by curve 200 of FIG. 2a which shows a dramatically reduced transition zone between elastic and plastic behavior of the torsion bar 70 and which has been achieved with pre-twisting as described above. The amount of pretwist will most probably vary with the diameter, length and material choice of the bar.

Reference is made to FIG. 5, which generally shows the construction of the major components of a torsion bar, energy absorbing seat belt retractor 20. The retractor 20 comprises a frame 22 with first and second sides 24a, 24b and a back 24c, each of the first and second sides includes a respective first opening 28a or 28b. The retractor 20 also includes a hollow spool 30 rotationally supported upon the frame.

The spool 30 includes a center body 32 and opposing flanges 34a, 34b at respective ends of the center body. The center body includes a hollow bore 40 having splines 42 formed at one end thereof. The body also includes means such as a slot (not shown) of known construction for receiving and securing an end of a length of seat belt (seat belt webbing) 36. Numeral 36a designates a few layers of the seat belt 36 wound about the spool.

A torsion bar 50 is received within the bore 40. The torsion bar includes a center body 52 and the end formations 52a, 52b. As mentioned, end formation 52b includes splines 56 (which drivingly engage with splines 42 of the spool). The notch or groove 58 (also see FIG. 4b) receives a driving key 60 of a spring arbor 62. The spring arbor includes a slot 64 in which is received an inner end of a rewind spring 66. The outer end of the rewind spring is secured to a spring cover 68. The cover is secured to frame side 24b and includes a circular projection 70 received within frame opening 28b. The circular projection serves as a bushing to rotationally support the spring arbor 62, torsion bar 50 and spool 30. The spool includes opposing pockets 38 located adjacent the splines 42 of the torsion bar 50. With the torsion bar in place, a tool is inserted into the pockets to locally deform the spool 30 to crimp the spool splines 42 and the torsion bar splines 56b together.

Emergency locking retractors (ELRs) include a variety of ratchet or lock wheel assemblies. The precise type for use in the present invention is not particularly important. As is known in the art, the ratchet wheel assemblies include a sensor means for causing a locking pawl to be brought into engagement with teeth on the ratchet or lock wheel to halt the protraction of the seat belt. Such means typically include the use of a vehicle or inertia sensor to sense vehicle deceleration above a predetermined level and a web sensor which is activated to initiate the locking of the retractor when the seat belt (webbing) is withdrawn from the spool at a rate in excess of a determinable level. The ratchet or lock wheel assemblies may use one or more plastic sensor pawls, which engage a plastic or metal ratchet wheel, which in turn couples a lock cup to the retractor shaft (in the present case to the torsion bar). Having coupled the lock cup to the shaft (torsion bar) the lock cup rotates. The motion of the lock cup moves a load absorbing, typically metal, locking pawl into engagement with a load absorbing metal lock wheel, thus halting, if only temporarily (when using energy absorbing components such as a torsion bar), the protraction of the seat belt. One such lock wheel assembly that is usable with the present invention is disclosed in US 5 529 258 or EP 0228729 which are incorporated herein by reference.

The end formation 52a of the torsion bar 50 is secured to a ratchet wheel assembly 80. The assembly includes a ratchet body 82 and lock or ratchet wheel 84 having teeth 85. The ratchet body includes a tubular portion 86 having internal splines 88 that engage the splines 56a of the torsion bar 50. The lock wheel may be a part of the body 82 or a separate part that is staked thereto as illustrated. The ratchet body is received within frame opening 28a and is supported by a bushing 90. A locking pawl 92 is rotationally supported upon the frame side 24a and is movable into engagement with the teeth 85 of the lock wheel 84 in response to the activation of a vehicle or web sensor.

The lock wheel assembly 80 includes a web sensor 220 that is coupled to sense the angular acceleration of rotation of the spool 30. As illustrated, the web sensor is coupled to the torsion bar 50 via the lock wheel assembly, the speed of which (prior to lockup) is that of the spool. The lock wheel assembly further includes a vehicle sensor 222. As mentioned above, the specific implementation of the web and vehicle sensors will vary, however, this is known in the art. Whenever either the vehicle or the web sensor is activated the lock pawl 92 is brought, via known mechanisms, into locking engagement with a lock wheel 84.

The operation of the retractor 20 is generally the same of that outlined above. During a crash, the end 52a of the torsion bar 50 is locked from further rotation and the seat belt is loaded as the vehicle occupant moves or attempts to move forward. The vehicle occupant load is transferred to the spool 30, via the belt 36, whose motion is opposed by the reaction torque generated as the spring end 52b of the torsion bar is rotated. Increased vehicle occupant load will cause the spool 30 and the torsion bar to rotate, in opposition to the reaction force, thereby protracting the seat belt 36 and permitting the vehicle occupant to move forward in a controlled manner.

The prior art has referred to energy absorbing seat belt retractors as constant force retractors. This reference is presumably to a theoretical constant plastic reaction torque (or force) that is achieved when the energy absorbing device, such as the torsion bar or crush ring, is deformed into its plastic region. Having generated this constant torque at for example the torsion bar, this force is communicated to the retractor spool and then to the seat belt. However, if the goal is to produce a retractor that displays a generally constant reaction force, even using a perfect torsion bar will not permit this. This can be seen by the following. The reaction force, F, on the seat belt is equal, in the steady state, to F = 0.5*D*T where F is the reaction force measured at the belt, D is the effective diameter of the spool plus any roll of seat belt webbing thereon and F is the reaction torque generated by the torsion bar. As the vehicle occupant loads the spool, the torsion bar begins to twist and generate a reaction torque. However, as the spool twists, more seat belt webbing is protracted off from the spool and the effective diameter, D, reduces. Consequently, even if the torque, T, is constant the belt reaction force may vary in correspondence to the belt removed from the spool.

FIG. 6 is test data for a crash simulation of using a 95th percentile hybrid III dummy and the above described torsion bar retractor. This test data shows that a retractor using the present invention can generate a reaction force that is remarkably constant. Prior to this test the seat belt webbing was extracted from the retractor and secured about the dummy so that about 3-4 layers of seat belt remained rolled on the spool. The effective diameter prior to testing was D = Ds + Dw, where Ds is the fixed diameter of the spool which is.41mm and Dw was the added width dimension due to the remaining 3-4 layers of seat belt on the spool. In this test condition D = 50 mm. The seat belt used was conventional woven polyester seat belt material with an elongation of about 6% and a thickness of about 1.27 mm. The resulting combination provided the near constant reaction force.

The claims defining the invention are as follows:

1. A seat belt retractor comprising:

a spool and a torsion bar, the torsion bar including first and second end formations, the first one of the end formations is connected to the spool; the torsion bar further comprises a ductile, elongated body, located between the end formations and formed by extruding an oversized metal bar into a bar of a reduced diameter with its grain structure in a vicinity of a center of the bar oriented in a longitudinal direction, the bar being annealed and twisted to establish a determinable work.

2. The seat belt retractor as defined in claim 1 wherein the end formations are formed by a cold heading process.

3. The seat belt retractor as defined in claim 2 wherein the second end formation is connected to a lock wheel assembly for locking during a crash to prohibit the second end of the torsion bar from rotating while permitting the first end and the spool to rotate while permitting a seat belt wound about the spool to be controllably protracted.

4. The seat belt retractor as defined in claim 1 wherein the torsion bar is twisted about 18 degrees.

5. A seat belt retractor comprising:

a frame;

a torsion bar comprising an extruded, reduced diameter center portion rotationally supported relative to the frame for generating a predetermined reaction torque as it is twisted, the torsion bar characterised by an elastic deformation zone and a sharp onset onto a plastic deformation zone;

a spool operatively connected to rotate with the torsion bar;

a lock means, adaptable during a vehicle crash and operatively connected to a first portion of the torsion bar for, at least temporarily stopping the torsion bar and the spool from rotating;

the spool having a seat belt positioned thereon, wherein with the lock means activated to prevent the first portion of the torsion bar from rotating and with a load applied to the seat belt, the spool and the torsion bar are rotatable in a direction of seat belt protraction opposed by the reaction force generated by the torsion bar as it twists.

6. The seat belt retractor as defined in claim 5 wherein the torsion bar is subjected to a pre-stress, prior to installation within the retractor sufficient to orient the grain structure of the bar longitudinally.

7. The seat belt retractor as defined in claim 5 wherein the torsion bar is subjected to a pre-stress, prior to installation within the retractor sufficient to product a sharp onset into a plastic deformation zone.

8. The seat belt retractor as defined in claim 5 wherein the torsion bar has a circular cross section.

9. A seat belt retractor comprising:

a spool having a determinable amount of seat belt stored thereon and a torsion bar, the torsion bar including first and second end formations, the first one of the end formations is drivingly connected to the spool;

the torsion bar further includes a ductile, elongated body, located between the end formations and formed by extruding an oversized metal bar into a bar of a reduced diameter with its grain structure in the vicinity of a center of the bar oriented in a longitudinal direction, the bar being annealed and twisted to establish a determinable work, the retractor generating a reaction force on the belt to oppose forward motion of an vehicle occupant in a crash, the reaction force being generally constant over a period of time as the seat belt protracts from the spool.

10. The seat belt retractor as defined in claim 9 wherein the effective diameter of the spool varies during the operation of the retractor.

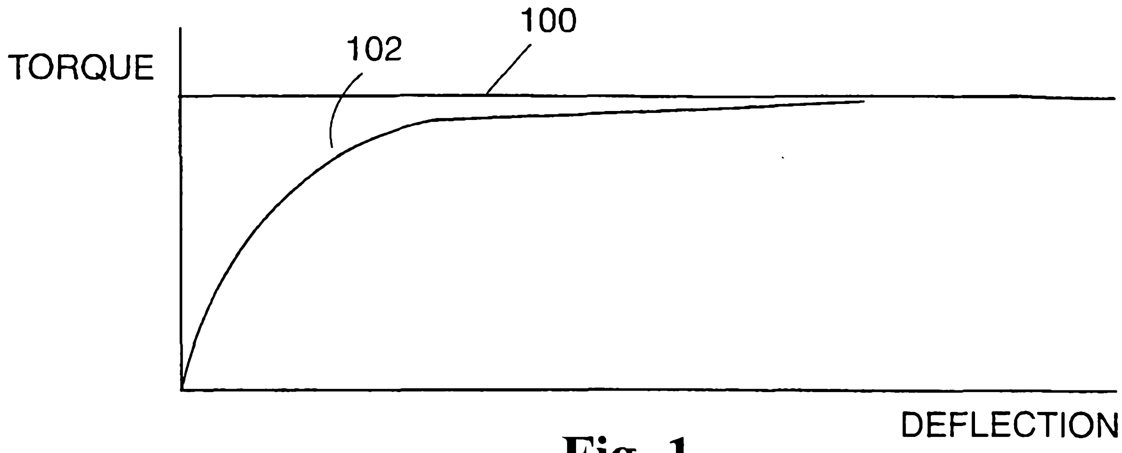
11. A seat belt retractor substantially as described herein with reference to Figs 3a to 5 of the accompanying drawings.

**Dated 7 May, 2002**

**Breed Automotive Technology, Inc.**

**Patent Attorneys for the Applicant/Nominated Person**

SPRUSON & FERGUSON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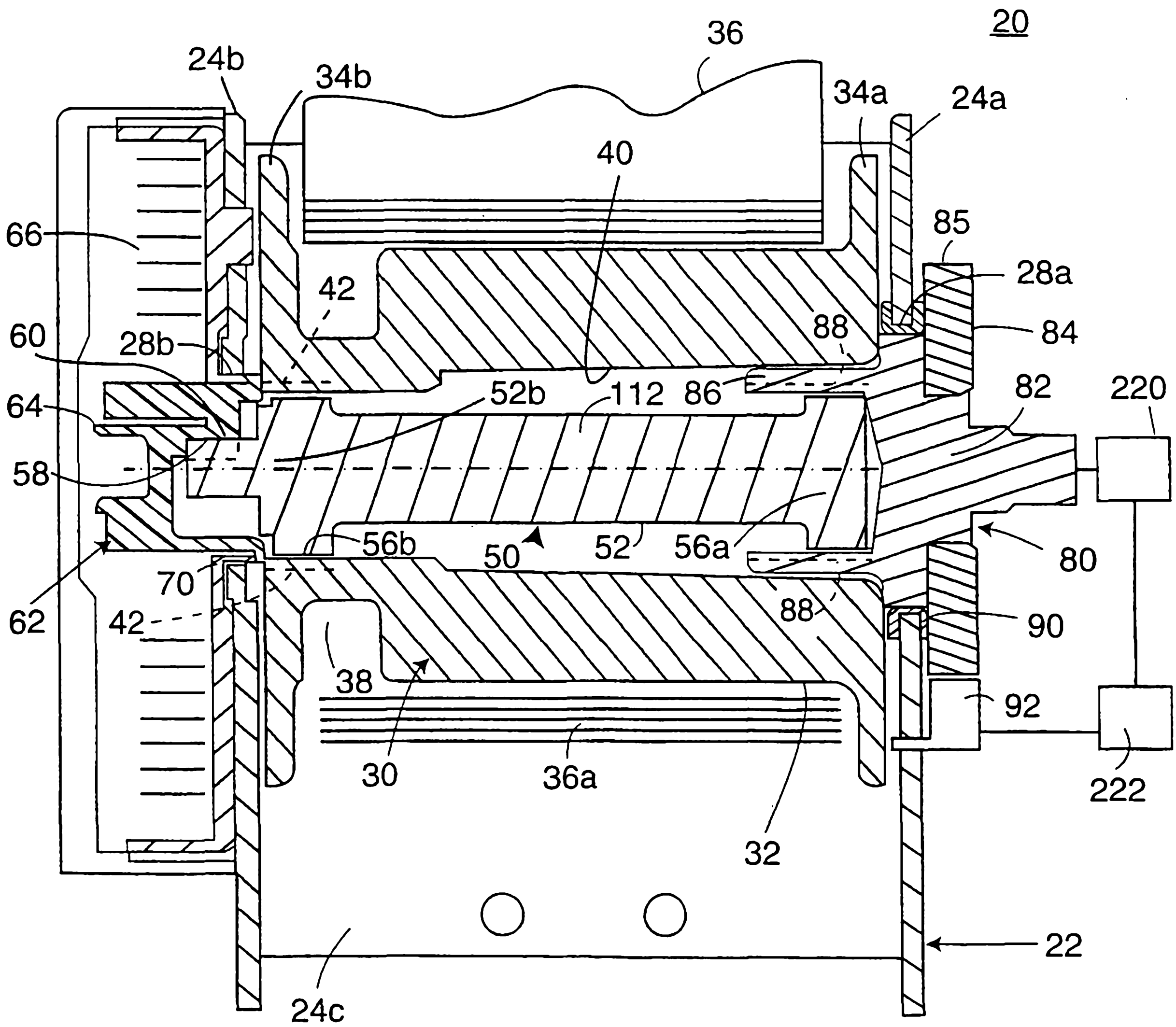
DEFLECTION

**Fig. 1**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24c
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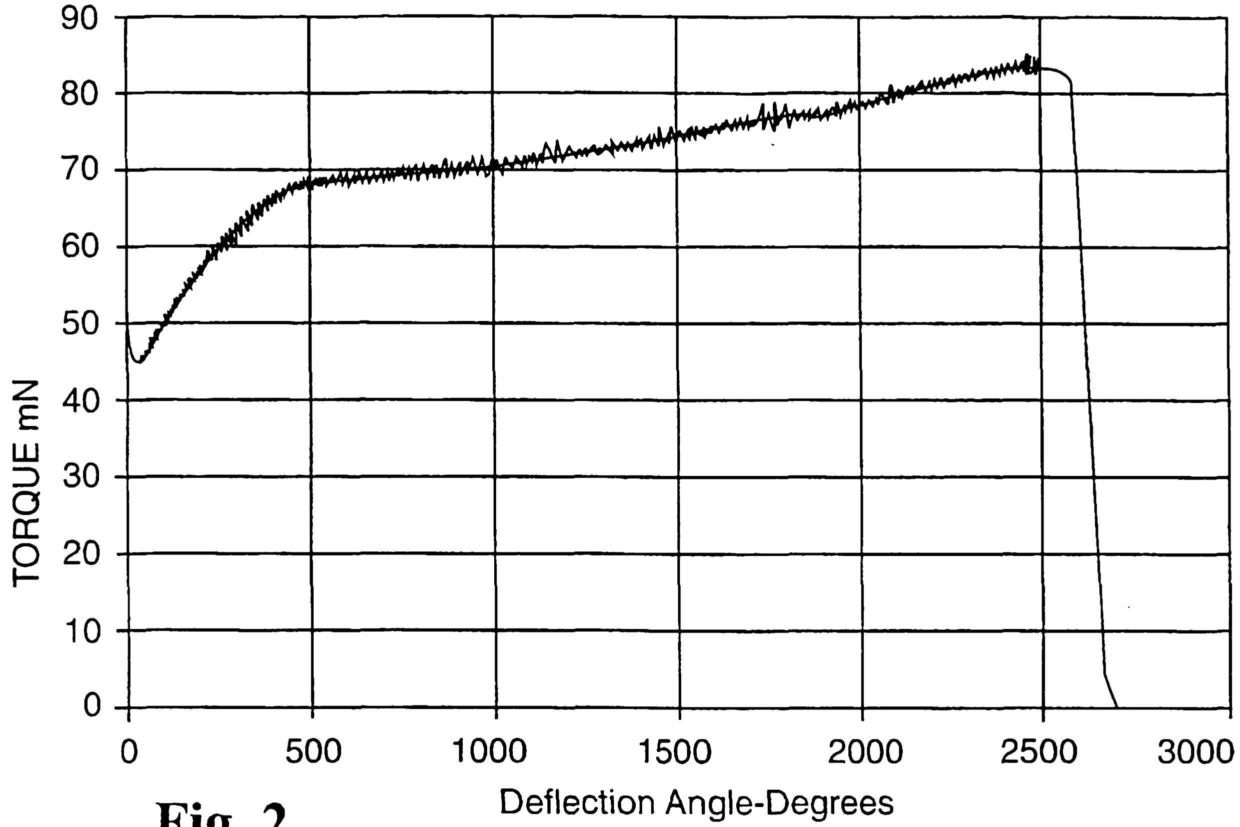
**Fig. 5**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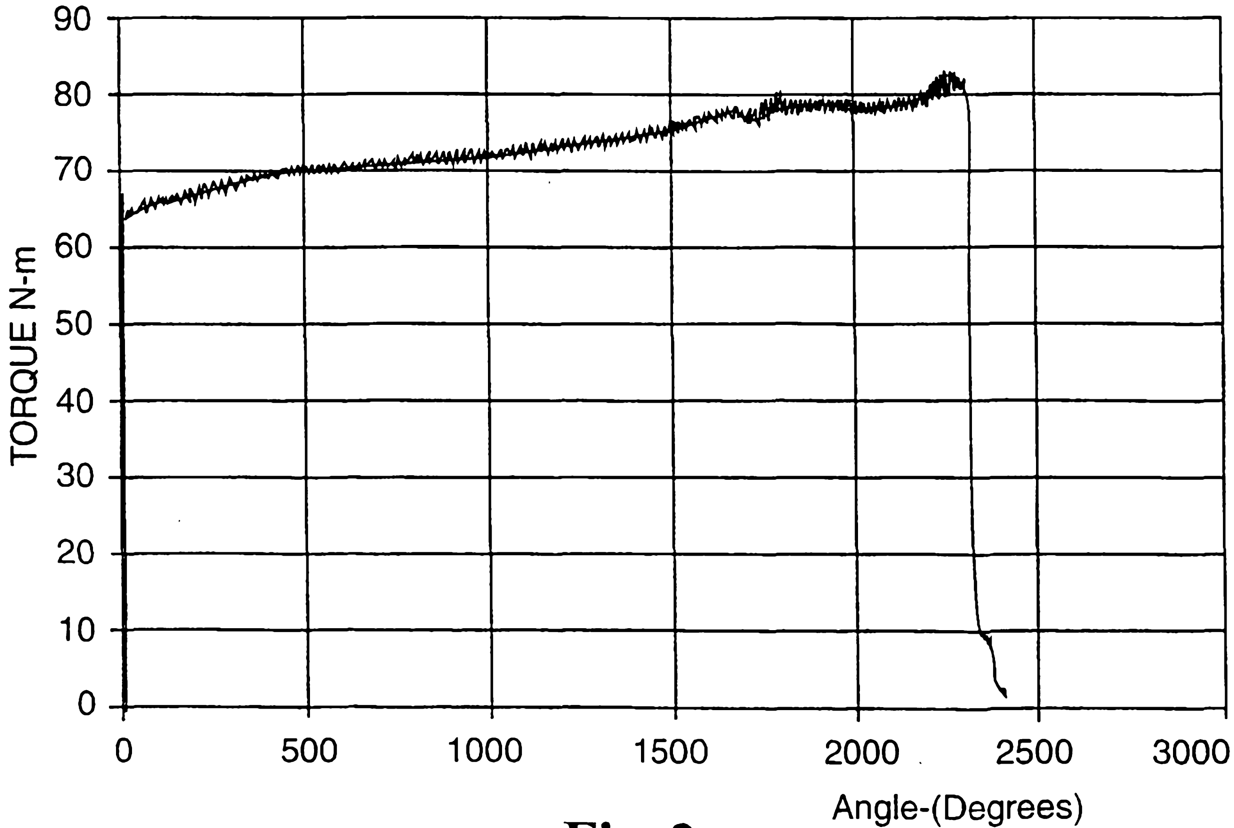
Deflection Angle-Degrees

**Fig. 2**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40
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500
1000
1500
2000
2500
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Angle-(Degrees)

**Fig. 2a**

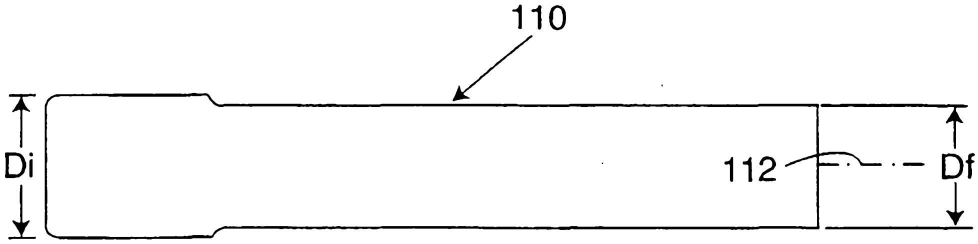


Fig. 3a

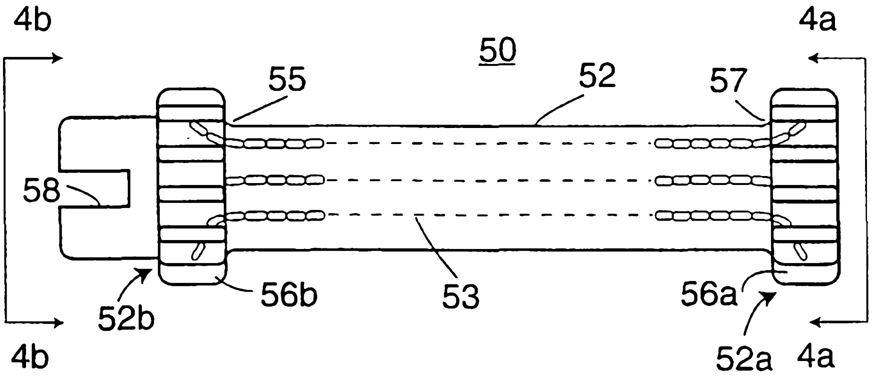


Fig. 3b

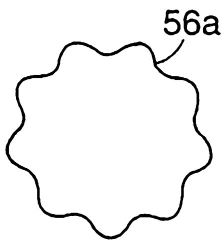


Fig. 4a

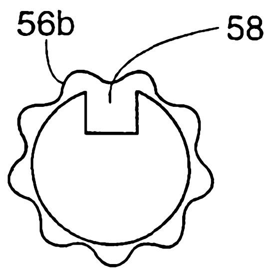


Fig. 4b

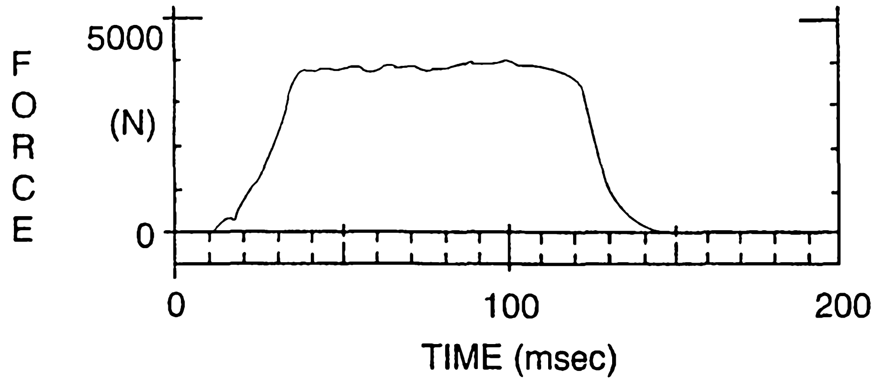


**Fig. 6**