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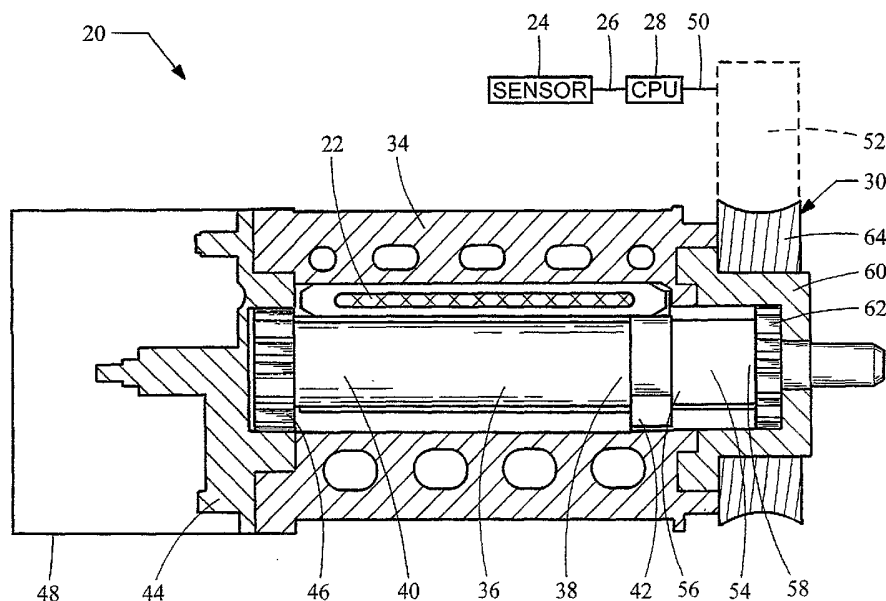
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(54) Title: ADAPTIVE RESTRAINT SYSTEM WITH RETRACTOR HAVING PRETENSIONER



(57) Abstract: A restraint system, its retractor (20), and related method provides adaptive load limitation characteristics and pretensioning. Factors such as occupant size or crash severity may be used in controlling the system. The adaptive restraint system generally includes a retractor (20) having a pretensioner (30), and through activation of the pretensioner the level of load limitation may be changed. A clutch (760) may also be employed between the pretensioner and the retractor.



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ADAPTIVE RESTRAINT SYSTEM WITH RETRACTOR HAVING PRETENSIONER

FIELD OF THE INVENTION

[0001] The present invention relates generally to seat belt restraint apparatus for restraining an occupant of an automobile, and more particularly relates to a retractor having a pretensioner for controlling load limitation aspects of the restraint system.

BACKGROUND OF THE INVENTION

[0002] Seat belt restraint systems for automobiles often include a pretensioner which is structured to apply tension to the seat belt when an impact event such as an accident situation is detected. When the pretensioner is activated, the pretensioner eliminates any slack in the seat belt, and thus controls the physical space between the occupant and the seat belt. In this manner, the occupant of the seat is coupled with the seat belt as the occupant initially moves forward relative to the seat, thereby controllably restraining the occupant, reducing occupant excursion, and preventing undue loads when the occupant moves forwardly into the seat belt.

[0003] A retractor is another standard component of a seat belt restraint system which includes a spool receiving the webbing material of the seat belt. The spool is used to wind up and store the webbing. Generally, the spool is locked in place upon detection at an impact situation in order to restrain the occupant via the seat belt. Recently, retractors have been designed having one or more force limiting elements which are structured to allow the spool to rotate and pay out the webbing material of the seat belt upon reaching predetermined force levels between the occupant and seat belt. In this manner, the restraint force imposed on the occupant can be limited in a controlled manner, thereby providing a certain load limitation characteristics.

[0004] Despite these and other improvements to automobile restraint systems, there remains a need to provide a retractor that includes a pretensioner while providing increased control and variation over the load limitation characteristics of the restraint system.

BRIEF SUMMARY OF THE INVENTION

[0005] One embodiment of the present invention provides a restraint system which adapts load limitation characteristics of the load between a seat belt and the occupant the belt restrains. The adaptive restraint system generally includes a crash sensor for detecting a potential crash event, a seat belt and retractor, and a controller. The retractor has a spool receiving the seat belt, and a locking mechanism operatively connected to the spool through a first force

limiting element. The retractor also includes a pretensioner having a drive mechanism operatively connected to the spool through a second force limiting element. The controller is operable in at least two modes, including a first mode where the controller effects activation of the pretensioner, and a second mode wherein the controller does not effect activation of the pretensioner. The controller determines the mode of operation based on at least one of a size of the occupant or a severity of the crash event. Preferably, the restraint system also includes a belt anchorage pretensioner operatively connected to the seat belt and activated in both the first and second modes.

[0006] Another embodiment of the present invention provides a retractor having a pretensioner that provides increased control and variation over the load limitation characteristics of the restraint system. The retractor generally includes a spool receiving a portion of the seat belt wound thereon. A first force limiting element is connected to the spool, and a locking mechanism is operatively connected to the spool through the first force limiting element to prevent paying out of seat belt, such as during an impact event. A second force limiting element is also connected to the spool, and operatively connects a drive mechanism of the pretensioner to the spool. The retractor is operable in at least two modes upon detection of an impact event, including a first load limiting mode and a second load limiting mode. In the first load limiting mode, the locking mechanism is activated to limit belt force through the first force limiting element. In the second load limiting mode, the drive mechanism of the pretensioner is activated to retract seat belt onto the spool and blocked to limit force through the second force limiting element, and the locking mechanism is activated to limit belt force through the first force limiting element. Optionally, the drive mechanism may include a locking element for blocking the drive mechanism. The retractor may also include a clutch positioned between the second force limiting element and one of the spool or the drive mechanism to provide increased adaptability.

[0007] Yet another embodiment of the present invention provides a method for restraining an occupant of an automobile. The method includes providing a retractor having a pretensioner, preferably of the construction noted above. The method further includes estimating at least one of a crash severity or an occupant size, and activating the drive mechanism of the pretensioner upon detection of an impact event to retract the seat belt onto the spool. The drive mechanism is activated when the estimation of crash severity or occupant size reaches a predetermined level.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The accompanying drawings incorporated in and forming a part of the specification illustrate several aspects of the present invention, and together with the description serve to explain the principles of the invention. In the drawings:

[0009] FIG. 1 is a cross-sectional view of a retractor constructed in accordance with the teachings of the present invention;

[0010] FIG. 2 is a graph depicting the belt load over time in the retractor of FIG. 1;

[0011] FIG. 3 is another graph depicting the belt load over time in the retractor of FIG. 1;

[0012] FIG. 4 is yet another graph depicting the belt load over time in the retractor of FIG. 1;

[0013] FIG. 5 is a schematic view, partially in cross-section, of another embodiment of the retractor constructed in accordance with the teachings of the present invention;

[0014] FIG. 6 is a schematic view, partially in cross-section, of yet another embodiment of a retractor constructed in accordance with the teachings of the present invention;

[0015] FIG. 7 is a front view of a sealing piston forming a portion of a pretensioner for the retractor;

[0016] FIG. 8 is a front view of another sealing piston forming a portion of a pretensioner for the retractor;

[0017] FIG. 9 is a schematic view of an adaptive restraining system constructed in accordance with the teachings of the present invention;

[0018] FIG. 10 is a flow chart describing a method of restraint using the system depicted in FIG. 9;

[0019] FIG. 11 is a cross-sectional view of a retractor constructed in accordance with the teachings of the present invention;

[0020] FIG. 12 is another cross-sectional view of the retractor depicted in FIG. 11;

[0021] FIG. 13 is a graph depicting the belt load over time in the retractor of FIG. 11;

[0022] FIG. 14 is another graph depicting the belt load over time in the retractor of FIG. 11;

[0023] FIG. 15 is a cross-sectional view of another embodiment of a retractor constructed in accordance with the teachings of the present invention;

[0024] FIG. 16 is another cross-sectional view of the retractor depicted in FIG. 15; and

[0025] FIG. 17 is a side view, partly in cross-section, depicting the retractor of FIG. 15.

DETAILED DESCRIPTION OF THE INVENTION

[0026] Turning now to the figures, FIG. 1 depicts a cross-sectional view of a retractor 20 constructed in accordance with the teachings of the present invention. The retractor 20 is adapted for an automobile having a seat belt 22 restraining an occupant (not shown). As is known in the art, the vehicle includes an impact sensor 24 sending a signal 26 indicative of an impact event such as a crash event. Any impact sensor that is or will be known to those skilled in the art may be readily employed in conjunction with the retractor 20 of the present invention. An electronic control unit 28 such as a central processing unit (CPU) or controller receives the signal 26 and controls the vehicle's response to the same.

[0027] Generally, the retractor 20 includes a pretensioner 30 formed with the retractor 20. As is known in the art, during normal use the retractor 20 is used to wind up the seat belt 22 about a spool 34. The spool 34 is coupled to a first force limiting element 36, which preferably comprises a torsion rod or torque bar, as is also known in the art. It will be recognized that other types of force limiting elements other than torsion rods may be employed in conjunction with the present invention, including sleeves, rings or tubes. The first force limiting element 36 generally includes a first end 38 and a second end 40. The first end 38 is connected to the spool 34 via a coupling 42, while the second end 40 is connected to a profiled head 44 via another coupling 46. Preferably, the coupling 42 is constructed as a low-profile spline as disclosed in U.S. Patent Application No. 11/008,308 filed December 9, 2004, the disclosure of which is incorporated herein by reference in its entirety.

[0028] The retractor 20 further includes an end assembly 48 which includes a locking mechanism that selectively engages the profiled head 44 and second end 40 of torsion bar 36 during an impact event such as a vehicle collision, providing an "emergency locking retractor" function as is well known in the art. For example, end assembly 48 is of the type disclosed in U.S. Patent Nos. 6,616,081; 6,012,667; and 5,924,641, the disclosures of which are hereby incorporated by reference in their entirety. Through blocking of the profiled head 44, the spool 34 is prevented from rotating and the occupant is restrained by the seat belt 22. However, the retractor 20 and first force limiting element 36 also provide a low load limitation function in order to limit the restraint force imposed on the occupant. Upon reaching a predetermined restraint force, the spool 34 will begin to rotate and "pay out" the seat belt 22 by actuation of the first force limiting element 36. That is, upon reaching a predetermined force, the torsion rod 36 will twist to allow some rotation of the spool 34 (as well as coupling 42 and first end 38) relative to the profiled head 44 (and hence relative to coupling 46 and second end 40) which is fixed by the locking mechanism of end assembly 48. In this manner, a first load limitation characteristic

is provided by the torsion of the first force limiting element 36 to allow limited pay out of the seat belt 22 wound on the spool 34.

[0029] Also shown in FIG. 1, a pretensioner 30 is provided for pretensioning the seat belt 22 through the retractor 20. The pretensioner 30 is activated by the electronic control unit 28 via a pretension signal 50. In particular, a drive mechanism 52 is actuated to effectuate rotation of the spool 34 via a second force limiting element 54. A first end 56 of the second force limiting element 54 is connected to the spool 38 via the shared coupling 42, although it will be recognized that the first end 56 may be directly attached to the spool 34 or include its own coupling. The second end 58 of the second force limiting element 54 is connected to an end cap 60 via a coupling 62. The end cap 60 is rotatable relative to the spool 34, and the friction therebetween is controlled by design, as discussed further herein. A pinion 64 is connected between the end cap 60 and the drive mechanism 52, whereby the clutch 64 selectively engages the end cap 60 upon activation of the drive mechanism 52.

[0030] It will be recognized by those skilled in the art that while the first ends 38, 56 of the first and second force limiting elements 36, 54 are located adjacent each other and are rigidly connected to the spool 34, the second force limiting element 54 and the pretensioner 30 could be connected to the second end 40 of the first force loading element 36, and more specifically connected to the profiled head 44. It will also be recognized that the first and second load limiting elements 36, 54 may be formed out of a single torsion bar wherein the opposing free ends of the bar would be selectively blocked (either via the locking mechanism or the pretensioner drive 52) to cause load limitation through the force limiting elements 36, 54. Further, the second force limiting element 54 could be a hollow tube which slides around a reduced diameter end of the torsion rod 36 forming the first force limiting element 36.

[0031] The retractor 20 is operable in at least two modes upon detection of an impact event. In a first load limiting mode, the pretensioner 30 is not activated while the tread head 44 is blocked by the locking element of end assembly 48. Accordingly, rotation of the spool 34 is blocked through the first load limiting element 36 and tread head 44, providing a first load limitation characteristic described further below. In a second load limiting mode, the pretensioner 30, and particularly its drive mechanism 52, is activated in addition to the blocking of the tread head 44. Accordingly, rotation of the spool 34 in the second mode is blocked through both the first and second load limiting elements 36, 54, providing a second load limitation characteristic also described further below.

[0032] The second load limiting mode includes a pretensioning phase and a load limiting phase. In the pretensioning phase, the slack between the seat belt 22 and the occupant is removed. In the load limiting phase, a limited amount of seat belt 22 is paid out in order to

control the level of belt force imposed on the occupant during the crash event. Upon determination of an impact event, either via the crash sensor 24 or a separate sensor incorporated into the pretensioner 30, the drive mechanism 52 drives the pinion 64 and end cap 60 to rotate the second force limiting element 54, which in turn rotates the spool 34 in a direction to wind up the seat belt 22 and remove any slack between the occupant and the seat belt 22. The second force limiting element 54 is preferably designed as a torsion rod, and preferably is capable of transmitting the pretensioning force from the drive mechanism 52 without significant deformation, although this is not required and the second torsion rod 54 may be partially deformed (i.e. loaded) during pretensioning.

[0033] In the load limiting phase of the second mode, after activation of the pretensioner 30 and in addition to blocking the tread head 44 to employ the first force limiting element 36, the end cap 60 is held in place such that any rotation of the spool 34 to pay out seat belt 22 will require deformation of the second load limiting element 54 (i.e. rotation of the coupling 42 and first end 56 relative to the coupling 62 and second end 58). When both the profiled head 44 and the end cap 60 are held in place, a second load limitation characteristic is provided through the combination of first force limiting element 40 and second force limiting element 50, which in this embodiment are superimposed.

[0034] The load limitation characteristics provided by the retractor 34 and pretensioner 30 will now be described with reference to the graphs depicted in FIGS. 2, 3 and 4 which present idealized data. In the figures, the Y-axis represents belt load while the X-axis represents time, and in FIG. 2 the dotted line 66 represents the low constant load limitation characteristic (preferably in the range of 2 kN to 3 kN) obtained when the pretensioner 30 is not activated, and hence the second force limiting element 58 is not effective, since both its ends 56, 58 are free to rotate. When the pretensioner 30 is activated, both the first and second force limiting elements 36, 54 are employed (since the pretensioner 30 blocks end 58 of the second force limiting element 54) to control the pay out of seat belt 22 by rotation of the spool 34, and thus a second load limitation characteristic is provided and is indicated by line 68 in the graph of FIG. 2. Thus, the second load limitation characteristic 64 shows a high constant load limitation which is preferably in the range of 5 kN to 6 kN.

[0035] It will be recognized by those skilled in the art that by employing two force limiting elements 36, 54, various other load limit characteristics may be achieved. In FIG. 3, the second load limitation characteristic 68 is provided with degressive load limitation. In particular, after reaching a predetermined belt load at point 69, the second load limitation characteristic 68 begins to decrease in any one of a number of manners, some of which are shown as lines 68a, 68b and 68c. In order to provide this degressive load limitation, the second

force limiting element 54 may be provided with various shapes or constructed of various materials which result in degressive load limits over time.

[0036] Similarly, and as shown in FIG. 4, the second force limiting element 54 may be superimposed on the first force limiting element 36 until a pre-selected number of spool rotations are reached. Then, the second force limiting element 54 is decoupled from the spool 34, preferably by shearing off the coupling 62 (or even the coupling 42), or alternatively by designed failure of the second force limiting element 54. In this manner, the second load limitation characteristic 68 will follow its standard course to a predetermined belt load 69, which will be maintained for a period of time and/or a number of spool rotations until point 67, at which time the limitation on the belt load will be reduced to a level close to the force level provided by the first load limitation characteristic 66. The difference between the first and second load limitation characteristics 66, 68 beyond point 67 represents the level of friction between the end cap 60 and spool 33, which may be designed to provide a specific amount of load limitation. More specifically, the pretensioner 30 and its drive mechanism 52 are still blocked, resulting in relative rotation between the end cap 60 and the spool 34. In this manner, a degressive load limitation may be provided for the second load limitation characteristic 68 via the second force limiting element 54, which is disconnected upon a predetermined number of spool rotations. It will also be recognized that a progressive load limitation could also be provided through design of the force limiting elements.

[0037] The present invention contemplates that various pretensioner devices and drive mechanisms may be coupled to the retractor 20 to provide pretensioning of the seat belt 22 and activation of the second force limiting element 54. For example, the pretensioner may have an electric motor or may be of the type having a driving mechanism that includes a pyrotechnic charge. One exemplary pretensioner is described in U.S. Patent No. 5,881,962, the disclosure of which is incorporated by reference herein in its entirety. Generally, ignition of the pyrotechnic charge or other combustible material creates a pressure in a chamber, which forces motion in a driving element such as a piston, rack, or series of elements such as balls. The driving element moves past a rotatable pinion or other force transmission device that is attached to the spool having the seat belt wound thereon, thereby causing retraction of the seat belt to remove slack between the belt and the occupant. After ignition, pressure in the chamber is maintained, such that the continued engagement of the driving element and the force transmission device (i.e. pinion) blocks any further protraction of the seat belt. Preferably, the pressure in the chamber is maintained by employing a driving element having specially designed sealing rings, examples of which are shown in FIGS. 7 and 8. In FIG. 7, the driving element 374 includes a core 375 and two arcuate sealing rings 376, while in FIG. 8 the driving element 474 includes a core 475

multiple sealing rings 476 having tapered ends 477. Accordingly, it can be seen that the blocking of a pyrotechnic pretensioner used in the retractor 20 of the present invention results in the blocking of one end of the second force limiting element 54, thereby affecting the load limitation characteristics.

[0038] It will also be recognized that additional means may be provided to assist in blocking the pretensioner. For example, and with reference to FIG. 5, an alternate embodiment of the retractor 120 is shown, schematically, including a pyrotechnic pretensioner device 130 constructed in accordance with the teachings of the present invention. Pretensioner 130 is coupled to the second force limiting element 154 via a pinion 164. The pinion 164 includes a plurality of teeth 170 which cooperatively engage teeth 172 on a pretensioner rack 174. It will be recognized that the teeth 170 do not initially engage teeth 172, thereby allowing the pinion 164 to freely rotate during normal operation. Alternatively, a clutch could be employed between the pinion 164 and the second force limiting element 154.

[0039] A drive mechanism 152 includes a combustion chamber 176 having a pyrotechnic charge 178 or other combustible material provided adjacent the rack 174, as is well known in the art. Upon activation of the pyrotechnic charge 178, the material expands to force the rack 174 linearly, in a downward direction in the figure as indicated by the lined arrow. The linear translation of the rack 174 is converted to a rotational movement of pinion 165 by the meshing engagement of teeth 170 of pinion 165 with teeth 172 of pretensioner rack 174. As pretensioner rack 174 is driven downward, pinion 165 is rotated in a direction indicated by the curved line arrow, thereby causing rapid winding of seat belt 122 onto the spool and hence pretensioning the seat belt 122.

[0040] In order to assist in the activation of the second force limiting member 154 during the load limiting mode of the retractor 120, the pretensioning rack 174 further includes a rack lock member 180. Rack lock member 180 is configured to engage one of a plurality of notches 182 disposed in housing 184 of pretensioner 132. A spring 186 is provided between rack 174 and lock member 180 to bias lock member 180 toward the plurality of notches 182 and thereby prevent upward movement of the rack 174. As such, the lock member 180 is a one-way locking element. Thus, as the rack 174 is driven downward, lock member 180 travels over the plurality of notches 182 and comes to rest in one of the notches when rack 174 stops moving. The locking of the rack 174 prevents rotation of pinion 165 and effectively locks the end cap 160 to prevent protraction of the seat belt 122 from retractor 120 and its spool. Of course, protraction of the seat belt 122 may still occur due to the twisting or torquing of second force limiting element 154 under loading of the seat belt 122 by the vehicle occupant.

[0041] Referring now to FIG. 6, another alternate embodiment of the retractor 220 is shown, schematically, including a different pretensioner device 230, constructed in accordance with the teachings of the present invention. The pretensioner 230 is coupled to a pinion 264, which in turn is connected to the second force limiting element 254. Pinion 264 is rotated by a drive mechanism 252 having pyrotechnic charge (not shown) as in the embodiment above. Here, the drive mechanism induces movement of pretensioner balls 274 through a roto pretensioner tube 284. The pretensioner tube 284 extends along the pinion 264 which includes recesses 270 sized to receive the balls 274. After firing the pretensioner 230, the leading ball 122 rotates the pinion 264 in order to initiate seat belt retraction (pull-in), as indicated by the curved lined arrow.

[0042] After passing the pinion 264, the leading ball shears off the retaining tap 288 of pinion lock 290. The retaining tap 288 holds a locking lever 292 in an unlocked position. The shearing off the retaining tap 288 releases the locking lever 292, which in turn is pushed by a lever spring 294 onto a toothed contour 296 of the pinion 265. The geometry of the lever 292 in conjunction with the lever spring 294 allows the pinion 265 to rotate in the pretensioning direction (pull-in) but blocks it in the load limiter direction (webbing protraction or pull-out). As such, the locking lever 292 is a one-way locking element. Of course, protraction of the seat belt may still occur due to the twisting or torquing of second force limiting element 254 under loading of the seat belt by the vehicle occupant.

[0043] It will be recognized by those skilled in the art that the retractor of the present invention provides increase adaptability and control over the load limitation characteristics imposed by the retractor and seat belt on an occupant, by providing additional load limitation through a second force limiting element via activation of the pretensioner. Further, the retractor reduces or eliminates "locking dip", which as used in the industry describes the phenomena of loss of belt load when the torque load is transferred from the pretensioner to the blocking element which blocks the profiled head to activate the force limiting element. By activating the pretensioner, and maintaining the activation of the second force limiting element while the first force limiting element is activated through blocking of the tread head, "locking dip" is substantially eliminated.

[0044] Using the retractor described above, control over the load limitation can be exercised based on several factors such as occupant type or size (i.e. 5th percentile occupant), crash severity, type of impact event, or the firing of other passive restraints such as airbags. Thus, an adaptive restraint system 520 may be provided in accordance with the teachings of the present invention, as will be described with reference to FIGS. 9 and 10. The adaptive restraint system 520 generally includes an occupant 510 positioned in the vehicle cabin 512 and sitting in

a seat 514, which could be any of the front or rear seats. The seat 514 is generally adjustable along a seat track 515 which provides translation of the seat 514 relative to the vehicle body 516. A seat belt 518 is provided for restraining the occupant 510 in the seat 514, and is coupled to a buckle 519 which may be operated by the occupant 510 for attaching or releasing the seat belt 518.

[0045] The restraint system 520 generally includes a crash sensor 522 sending a signal 524 indicative of a crash event or a potential crash event (in which case the signal 524 would be outputted upon reaching a predefined crash sensitivity). Any crash sensor that is or will be known to those skilled in the art may be readily employed in conjunction with the restraint system 520 of the present invention. An electronic control unit 526 receives the crash signal 524 and controls the vehicle's response to the same. In accordance with the present invention, the electronic control unit 526 sends control signals 528 to various devices, including a first pretensioner 530 and/or a second pretensioner 532. The first pretensioner 530 is preferably any type of belt anchorage pretensioner that is or will be known to those skilled in the art. In FIG. 1, the belt anchorage pretensioner 530 has been depicted as a buckle pretensioner and is connected to the buckle 519 for retracting the same to pretension the seat belt 518 around the occupant 510. One exemplary buckle pretensioner is disclosed in U.S. Patent No. 6,726,250, the disclosure of which is incorporated herein by reference in its entirety. It will also be recognized that other belt anchorage pretensioners may be employed such as shoulder strap or lap belt anchorage pretensioners; exemplary pretensioners being disclosed in U.S. Patent No. 6,626,463, the disclosure of which is incorporated herein by reference in its entirety.

[0046] A second pretensioner 532 is specially formed as part of a retractor 534, preferably taking the form of the previously described retractor 20 having pretensioner 30. An occupant sensor 536 is also provided for estimating a relative size of the occupant 510. Preferably, the occupant sensor 536 is a simple electrical switch which can be triggered upon translation of the seat 514 along the seat track 515. Specifically, the sensor 536 of the present invention is designed to distinguish between fifth percentile female occupants and fifty percentile occupants, i.e. the 5th percentile small female dummy versus 50th percentile average dummies. Thus, the switch 536 may be located at a predetermined position along the seat track 515 to distinguish between these relative sizes of the occupant 510. While a simple seat track switch 536 is described here, numerous other occupant sensors that are or will be known to those skilled in the art may be employed, including but not limited to occupant weight sensors, pedal position sensors, occupant position sensors, seat position sensors, low "G" sensors, high "G" sensors and belt displacement or latching sensors. No matter which type of sensor 536 is used, the occupant sensor 536 sends a signal 537 back to the electronic control unit 526 with

information indicative of the relative size of the occupant 510. It will also be recognized that the occupant size variable may be readily replaced with other aforementioned variables such as crash severity, crash type, or deployment of other passive restraints.

[0047] It will now be recognized by those skilled in the art that the adaptive restraint system 520 of the present invention is capable of providing a method for restraining the occupant 510 in a manner which is adaptive to the particular size of the occupant 510. With reference to FIG. 10, the method includes providing the restraint system depicted in FIGS. 9, in which the occupant type may be sensed by seat switch 536, as indicated at block 670. The method then flows to block 672, in which a potential crash is sensed via crash sensor 522. At decision block 674, a potential crash is either detected or not detected. When a potential crash is detected, the method activates the belt anchorage pretensioner 530 (block 676), since this pretensioner 530 is activated irregardless of the size of the occupant 510. It is then confirmed at block 678 whether the occupant is greater than or equal to the fifth percentile occupant or other predetermined occupant size. If the occupant is above the predetermined size, the method further activates the retractor pretensioner 532 as indicated at block 680, before the method flows to its end at block 682.

[0048] By activating only the belt anchorage pretensioner 530 when the occupant 510 is sensed to be less than a predetermined level representative of the 5th percentile female occupant, single pretensioning is provided and a first load limitation characteristic is provided through the first force limiting element 36. Since the retractor pretensioner 532 is not activated, the second force limiting element 54 is not activated for this occupant, and a low constant load limitation is provided as a first load limitation characteristic 66. In the event that the occupant is greater than or equal to the predetermined level and has a relative size in the range of the 50th percentile occupant, the retractor pretensioner 532 will be activated in addition to the belt anchorage pretensioner 530. Thus, double pretensioning will be provided, as well as a second load limitation characteristic which is characterized by both the first and second force limiting elements 36, 54. Depending on the particular embodiment, and specifically the selection and structure of the second force limiting element 54 and its connections to the end cap 60 and spindle 34, either a high constant load limitation or a degressive load limitation may be provided for the second load limitation characteristic 68.

[0049] Turning now to FIGS. 11-14, additional control of the load limitation is provided by another embodiment of a retractor 720 constructed in accordance with the teachings of the present invention. As will be described in more detail below, the retractor 720 includes a pretensioner 750 which is selectively connected to the retractor spool 730 through a clutch 760, thereby achieving greater control over the load limitation.

[0050] As best seen in FIG. 11, the retractor 720 is adapted for an automobile having a seat belt 722 restraining an occupant (not shown). As is known in the art, the vehicle includes an impact sensor 724 sending a signal 726 indicative of an impact event such as a crash event. Any impact sensor that is or will be known to those skilled in the art may be readily employed in conjunction with the retractor 720 of the present invention. An electronic control unit 728 such as a central processing unit (CPU) or other controller receives the signal 726 and controls the vehicle's response to the same. During normal use the retractor 720 is used to wind up the seat belt 722 about a spool 730 which is rotatably mounted to a frame 732 of the retractor 720. The spool 730 is coupled to a first force limiting element 734, which preferably comprises a torsion rod or torque bar. The first force limiting element 734 generally includes a first end 736 and a second end 738. The first end 36 is connected to the spool 730 via a coupling 740, while the second end 738 is connected to a profiled head 744 via another coupling 742.

[0051] The retractor 720 further includes an end assembly 746 which includes a locking mechanism that selectively engages the profiled head 744 and second end 738 of torsion bar 734 during an impact event such as a vehicle collision, providing an "emergency locking retractor" function as is well known in the art. Through blocking of the profiled head 744, the spool 730 is prevented from rotating and the occupant is restrained by the seat belt 722. However, the retractor 720 and first force limiting element 734 also provide a low load limitation function in order to limit the restraint force imposed on the occupant. Upon reaching a predetermined restraint force, the spool 730 will begin to rotate and "pay out" the seat belt 722 by actuation of the first force limiting element 734. In this manner, a low load limitation characteristic is provided by the torsion of the first force limiting element 734 to allow limited pay out of the seat belt 722 wound on the spool 730.

[0052] Also shown in FIG. 11, the retractor 720 includes a pretensioner 750 for pretensioning the seat belt 722 through the retractor 720. The pretensioner 50 is activated by the electronic control unit 728 via a pretension signal 748. In particular, a drive mechanism 752 is actuated to effectuate rotation of the spool 730 via a second force limiting element 754. A first end 756 of the second force limiting element 754 is connected to the spool 738 via the shared coupling 740, although it will be recognized that the first end 756 may be directly attached to the spool 730 or include its own coupling. The drive mechanism 752 of the pretensioner 750 is connected to the second end 758 of the second force limiting element 754 by way of a clutch 760 and a coupling 762 at the second end 758 of the second force limiting element. Preferably, the drive mechanism 752 is initially disengaged from the pinion 764 so that the spool 730 may freely rotate during normal operation of the retractor 720. As is known, upon activation of the pretensioner 750, the drive mechanism 752 engages the pinion 764 for transmitting force

therebetween. At about the same time as the blocking of the pretensioner 750, the profiled head 744 is blocked by the locking mechanism. Thus, through activation of the pretensioner 750, rotation of the spool 730 is blocked through both the first and second load limiting elements 734, 754, providing a high load limitation function to control the restraint force imposed on the occupant.

[0053] For increased control over the level of load limitation provided by the retractor 720, the clutch 760 is constructed to permit selective connection of the pretensioner 750 and its pretensioner drive 752 to the second force limiting element 754 and spool 730. More specifically, the initial position of the clutch 760 connects the pretensioner 750 to the spool 730 for pretensioning of the seat belt 722 and high load limitation through blocking of the pretensioner 750, as described above. The activated position of the clutch 760 decouples the pretensioner 750 and spool 730, as will be described below. Generally, the CPU 728 will generate a clutch signal 766 to decouple the pretensioner 750, based on such factors as occupant type or size (i.e. 5th percentile occupant), crash severity or type of impact event, and the firing of other passive restraints such as air bags or other restraint apparatus.

[0054] Upon receiving a clutch signal 766 from the CPU 728, a clutch drive 761 includes pyrotechnic charge 768 or other combustible material that is ignited inside a combustion chamber 770. The pressure in the chamber 770 presses on a driving element 772 which engages a hub 774. As shown in FIG. 12, the hub 774 is interposed between the pinion 764 of the drive mechanism 752 and the coupling 762 of the second force limiting element 754. The hub 774 includes a tongue 776 received in a groove 778 of the pinion 764, thereby rotatably coupling the two pieces. Similarly, the hub 774 includes at least one shank 780 projecting radially inwardly for engagement with a shoulder 782 of the coupling 762. As best seen in FIG. 1, upon axial translation of the hub 774 by the driving element 772, the hub 774 may be positioned in and out of engagement with the coupling 762 of the second force limiting element 754.

[0055] Further, the clutch 760 includes a spring 784 or other resilient member biasing the hub 772 into a position engaged with the coupling 762. As such, the clutch 760 includes an initial position where the pretensioner drive mechanism 752 is operatively coupled to the second force limiting element 754 and spool 730. In an activated position, the hub 774 is driven such that the clutch 760 operatively decouples the drive mechanism 752 and the spool 730 via the second force limiting element 754. Finally, it can also be seen in FIG. 1 that the clutch 760 includes a relief valve 786 coupled to the combustion chamber 770. As such, pressure within the chamber 770 may be selectively released (such as via another clutch signal 766 or other direct signal) and the hub 774 retracted axially, thereby providing a deactivated position where

the drive mechanism 752 is again coupled to the second force limiting element 754 and spool 730.

[0056] The load limitation characteristics provided by the retractor 720 and pretensioner 750, as controlled through the clutch 760 will now be described with reference to the graphs depicted in FIGS. 13 and 14 which present idealized data. In the figures, the Y-axis represents belt load while the X-axis represents time. Upon detection of an impact event, the CPU 728 will send a pretensioning signal 748 to the pretensioner 750 to initiate its drive mechanism 752. The pretensioner drive mechanism 752 rotates the spool 730 via the second force limiting element 754 until the pretensioner 750 is blocked. At about the same time, the pretensioner 750 is blocked, the profiled head 744 blocks the second end 738 of the first load limiting element 734, and rotation of the spool 730 is prevented except through the controlled rotation provided by the first and second force limiting elements 734, 754. As such, the load limitation provided by the first and second force limiting elements 734, 754 are superimposed to provide a high load limitation characteristic depicted as line 792 in FIG. 13. At any point during the impact event (such as points 794, 794b, 794c, 794d), the CPU 728 may determine that a lower load limitation level is desired, and thus send the clutch signal 766 to activate the clutch 760. As previously discussed, in the activated position the clutch 760 decouples the pretensioner drive mechanism 752 from the second force limiting element 754 and spindle 730. In this activated position of the clutch 760, the load limitation is provided solely through the first load limiting element 734, which provides a low load limitation characteristic, indicated by line 790. Similarly, if at some point 796a, 796b CPU 728 determines higher load limitation is desired, a clutch signal 766 may again be sent to deactivate the clutch through the relieving pressure in the chamber 770 via relief valve 786.

[0057] It will also be recognized by those skilled in the art that the initial, activated and deactivated positions of the clutch 760 may be reversed, as will be described with reference to FIG. 11. For example, if the shoulders 782 of the coupling 762 were moved to the left side of the coupling 762 in FIG. 11, such that the hub 774 is not initially in engagement with the shoulders 782 of coupling 762, the initial position of the clutch 760 would be to decouple the pretensioner drive mechanism 752 and the second force limiting element 754. Thus, upon activation of this reversed clutch mechanism 760, the pretensioner drive mechanism 752 would be coupled to the spool 730 via the second force limiting element 754, and upon deactivation of the clutch 760 the drive 752 and spool 730 would again be decoupled. As such, when an impact event is detected and the CPU 728 decides not to fire the pretensioner 750, the profiled head 744 may be locked to provide a low load limitation characteristic 790. Then, the CPU 728 could initiate the pretensioner drive mechanism 752, and when the pretensioner 750 is blocked,

activate the clutch 760 to provide load limitation through both the first and second load limiting elements 734, 754. Thus, at any point 794a, 794b, 794c in time the retractor 720 can be switched to a high load limitation characteristic as indicated by line 792. Finally, the clutch 760 could then be deactivated at another point in time 796a, 796b in order to return to low load limitation 790 through the first force limiting element 734.

[0058] Turning now to FIGS. 15, 16 and 17, another embodiment of the retractor 820 having a pretensioner 850 with a clutch 860 has been depicted in accordance with the teachings of the present invention. Generally, the retractor 820 and the pretensioner 850 with its drive 852 are of a substantially similar construction as the prior embodiment described with reference to FIGS. 11-14. In this embodiment, however, the clutch mechanism 860 is provided between the second force limiting element 854 and the spool 830. As in the prior embodiment, the spool 830 is rotatably mounted and is coupled to a first load limiting element 834 via a coupling 840. Here, the second force limiting element 854 does not share the coupling 840, but rather includes its own coupling 863 at its first end 856. As best seen in FIG. 16, the coupling 863 defines a pair of shoulders 865 which are sized to receive a pair of coupling pawls 867. The pawls 867 are pivotally mounted to the spool 830 for rotation in and out of engagement with the shoulders 865. Engagement of the pawls 867 with the shoulders 865 is maintained by the provision of a spool ring 166 that is axially translatable. In FIG. 15, the spool ring 866 has been shown in the engaged position, wherein a pair of tabs 869 project radially inwardly to prevent rotation of the coupling pawls 867 and force engagement with the coupling 863 of the second force limiting element 854. Thus, in this activated position shown in FIGS. 15 and 16, force transmission from the second load limiting element 854 to the spool 830 is provided through the clutch 860.

[0059] As best seen in FIG. 17, axial translation of the spool ring 866 is effected through a set collar 872 which is arranged in the frame 832 of the retractor 820. The clutch 860 includes a drive 861 having a pyrotechnic charge 868 that impacts a piston 870 causing its linear movement. In its linear movement, the piston 870 acts on a shoulder 871 projecting radially from the set collar 872, such that the set collar 872 is caused to rotate when the piston 870 is actuated. The set collar 872 is connected to the frame 832 such that it does not rotate during the normal function of the spool 830, but can perform a limited rotational movement during its adjusting motion. Particularly, the set collar 872 is supported against the frame 832 by inclined ramps (not shown) such that through rotation of the set collar 872 axial displacement occurs, thereby forcing axial displacement of the spool ring 866 by virtue of their adjacent position.

[0060] Another embodiment of the retractor 720, 820 could employ multiple clutches, such as both clutch 760 and clutch 860 previously described. In this case, the pretensioner drive

752, 852 can be initially engaged with the pinion 764, 864, which would occur at about the same time as the actuation of the pretensioner 750, 850 to force transmission.

[0061] It will be recognized by those skilled in the art that the retractor 720, 820 of the present invention provides increase adaptability and control over the load limitation characteristics imposed by the retractor and seat belt on an occupant, by providing additional load limitation through a second force limiting element and activation of the pretensioner which can be selectively controlled via the clutch 760.

[0062] The foregoing description of various embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise embodiments disclosed. Numerous modifications or variations are possible in light of the above teachings. The embodiments discussed were chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

CLAIMS

1. An adaptive restraint system for an automobile having a seat for an occupant and a crash sensor for detecting a potential crash event, the system comprising:
 - a seat belt for restraining the occupant in the seat;
 - a retractor having a spool receiving the seat belt, the retractor including,
 - a first force limiting element connected to the spool,
 - a locking mechanism operatively connected to the spool through the first force limiting element,
 - a second force limiting element connected to the spool,
 - a pretensioner having a drive mechanism operatively connected to the spool through the second force limiting element, and
 - a controller operating the retractor in at least two modes including a first mode wherein the controller activates the drive mechanism of the pretensioner to retract the seat belt onto the spool and limit force through the second force limiting element, and a second mode wherein the controller does not activate the pretensioner, the controller determining the mode of operation based on at least one of a size of the occupant or a severity of the crash event.
2. The system of claim 1, wherein in the first mode the second force limiting element absorbs belt force caused by the occupant pressing on the seat belt.
3. The system of claim 1, wherein the first and second modes provide different first and second load limitation characteristics, respectively.
4. The system of claim 3, wherein the load limitation of the first and second force limiting elements are superimposed to characterize the first load limitation characteristic.
5. The system of claim 1, wherein the both the first and second modes include activation of the locking mechanism to limit force through the first force limiting element.
6. The system of claim 1, wherein the first mode provides a high constant load limitation characteristic.

7. The system of claim 1, wherein the first mode includes a pretensioning phase wherein the drive mechanism of the pretensioner rotates the spool, and a load limiting phase wherein the drive mechanism is blocked.

8. The system of claim 1, the automobile including an occupant sensor for estimating the size of the occupant, wherein the controller operates in the first mode when the occupant is estimated to be above a predetermined size, and wherein the controller operates in the second mode when the occupant is estimated to be at or below the predetermined size.

9. The system of claim 1, further comprising a belt anchorage pretensioner operatively connected to the seat belt for providing pretensioning of the seat belt, wherein in the first mode the controller effects activation of both the belt anchorage pretensioner and the pretensioner, and wherein in the second mode the controller effects activation of only the belt anchorage pretensioner.

10. An adaptive restraint system for an automobile having a seat for an occupant and a crash sensor for detecting a potential impact event, the system comprising:

- a seat belt for restraining the occupant in the seat;
- a retractor comprising,
 - a spool receiving a portion of the seat belt,
 - a first force limiting element connected to the spool,
 - a locking mechanism operatively connected to the spool through the first force limiting element,
 - a second force limiting element connected to the spool, and
 - a pretensioner having a drive mechanism operatively connected to the spool through the second force limiting element; and
- the retractor operable in at least two modes upon detection of a potential impact event including,
 - a first load limiting mode wherein the locking mechanism is activated to limit belt force through the first force limiting element, and
 - a second load limiting mode wherein the drive mechanism of the pretensioner is activated to retract seat belt onto the spool and blocked to limit force through the second force limiting element, and wherein the locking mechanism is activated to limit belt force through the first force limiting element.

11. The system of claim 10, wherein the drive mechanism includes a pyrotechnic charge.

12. The system of claim 11, wherein the drive mechanism is blocked by maintaining pressure generated by the pyrotechnic charge.

13. The system of claim 10, wherein the drive mechanism includes a one-way locking element for blocking the drive mechanism.

14. The system of claim 10, wherein the locking mechanism is activated after the drive mechanism of the pretensioner has been blocked.

15. The system of claim 10, further comprising a selectively actuatable clutch positioned between the second force limiting element and one of the spool or the drive mechanism, the selectively actuatable clutch controlling force transmission between the spool and the drive mechanism.

16. The system of claim 15, wherein the selectively actuatable clutch includes an initial position and an activated position, and wherein the initial position couples the drive mechanism and the spool for force transmission, and the activated position decouples the drive mechanism and the spool.

17. The system of claim 15, wherein the selectively actuatable clutch includes an initial position and an activated position, and wherein the initial position decouples the drive mechanism and the spool, and the activated position couples the drive mechanism and the spool for force transmission.

18. The system of claim 15, wherein the selectively actuatable clutch is positioned between the second force limiting element and a pinion of the drive mechanism.

19. The system of claim 18, wherein the selectively actuatable clutch includes a hub and a clutch drive mechanism, the hub, pinion and second force limiting element including

corresponding engagement features, the clutch drive mechanism axially translating the hub to engage pinion and second force limiting element.

20. The system of claim 15, wherein the selectively actuatable clutch is positioned between the second force limiting element and the spool.

21. A method for restraining an occupant of an automobile having seat belt securing the occupant and a sensor detecting a potential impact event, the method comprising:

providing a retractor having a pretensioner, a spool, a first force limiting element, a second force limiting element, and a locking mechanism, the spool receiving a portion of the seat belt, the first force limiting element operatively connecting the spool and locking mechanism, the pretensioner having a drive mechanism, the second force limiting element operatively linking the spool and drive mechanism;

estimating at least one of a crash severity or an occupant size;

activating the drive mechanism of the pretensioner to retract seat belt onto the spool and limit force through the second force limiting element when the estimation of crash severity or occupant size reaches a predetermined level.

22. The method of claim 21, wherein the step of activating the drive mechanism of the pretensioner includes blocking the drive mechanism during the impact event to provide load limitation via the second force limiting element.

23. The method of claim 22, wherein the drive mechanism is blocked throughout the impact event.

24. The method of claim 22, wherein the step of blocking the drive mechanism includes the second force limiting element absorbing belt force caused by the occupant pressing on the seat belt.

25. The method of claim 22, further comprising the step of activating the locking mechanism to limit belt force through the first load limiting element after the drive mechanism of the pretensioner has been blocked.

26. The method of claim 21, wherein the step of activating the drive mechanism includes activating a one-way locking element for maintaining the position of the drive mechanism of the pretensioner.

27. The method of claim 21, wherein the second force limiting element contributes to the load limitation characteristic of the system only when the pretensioner is activated.

28. The method of claim 21, further comprising the steps of:
providing an occupant sensor for estimating a relative size of the occupant,
providing a controller receiving signals from the crash sensor and the occupant sensor,
and
activating the retractor pretensioner when the occupant is estimated to be greater than or equal to a predetermined size and upon sensing a potential crash event.

29. The method of claim 21, further comprising the steps of:
providing a belt anchorage pretensioner operatively connected to the seat belt for pretensioning of the seat belt; and
activating the belt anchorage pretensioner upon sensing a potential crash event.

30. The method of claim 29, wherein activation of both the retractor pretensioner and the belt anchorage pretensioner provide a first load limitation characteristic, and wherein activation of only the belt anchorage pretensioner provides a second load limitation characteristic different from the first load limitation characteristic.

31. The method of claim 30, wherein the first and second force limiting elements characterize the first load limitation characteristic.

32. The method of claim 30, wherein the first force limiting element characterizes the second load limitation characteristic.

33. The method of claim 21, further comprising the steps of:
providing a selectively actuatable clutch interposed between the second force limiting element and one of the drive mechanism or the spool, the selectively actuatable clutch having an initial position coupling the second force limiting element from the drive mechanism or the spool; and

switching the clutch drive mechanism to an activated position decoupling the second force limiting element from one of the drive mechanism or the spool.

34. The method of claim 33, wherein the switching step occurs a predetermined time after detection of an impact event.

35. The method of claim 33, further comprising the step of switching the clutch drive mechanism to a deactivated position coupling the second force limiting element to one of the drive mechanism or the spool.

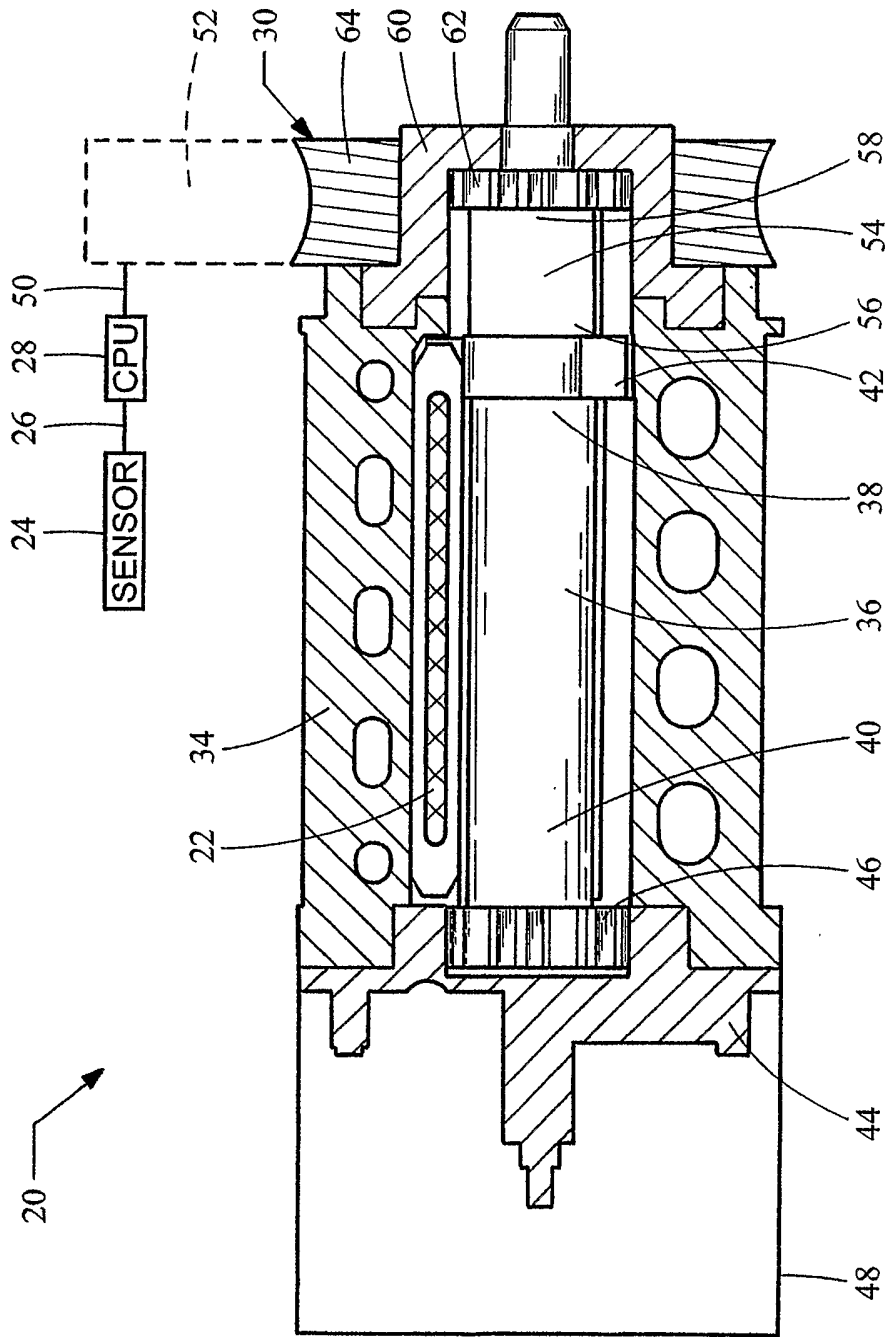


Fig. 1

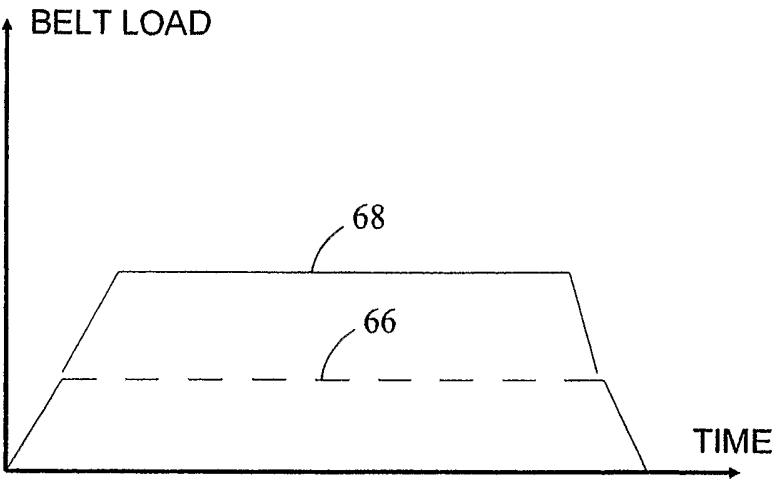


Fig. 2

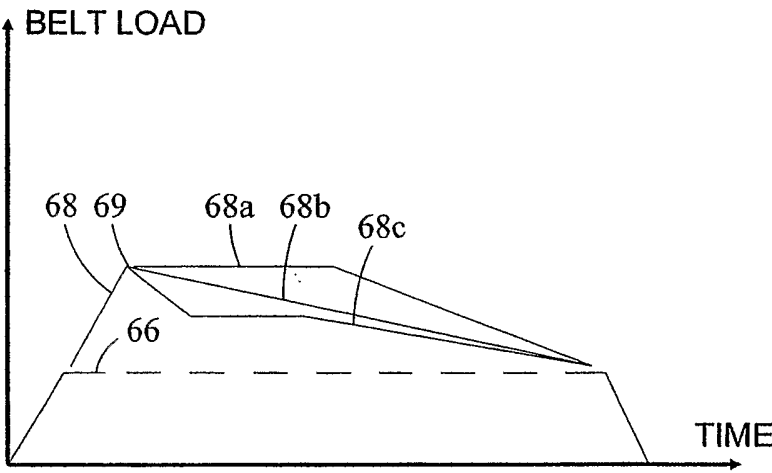


Fig. 3

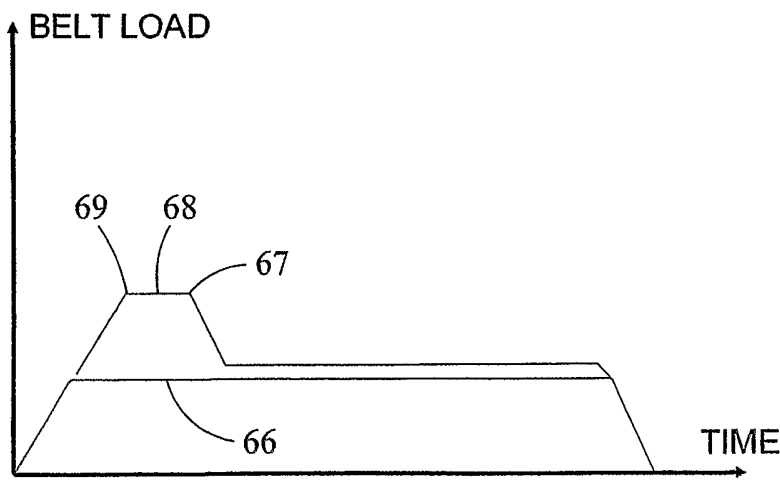


Fig. 4

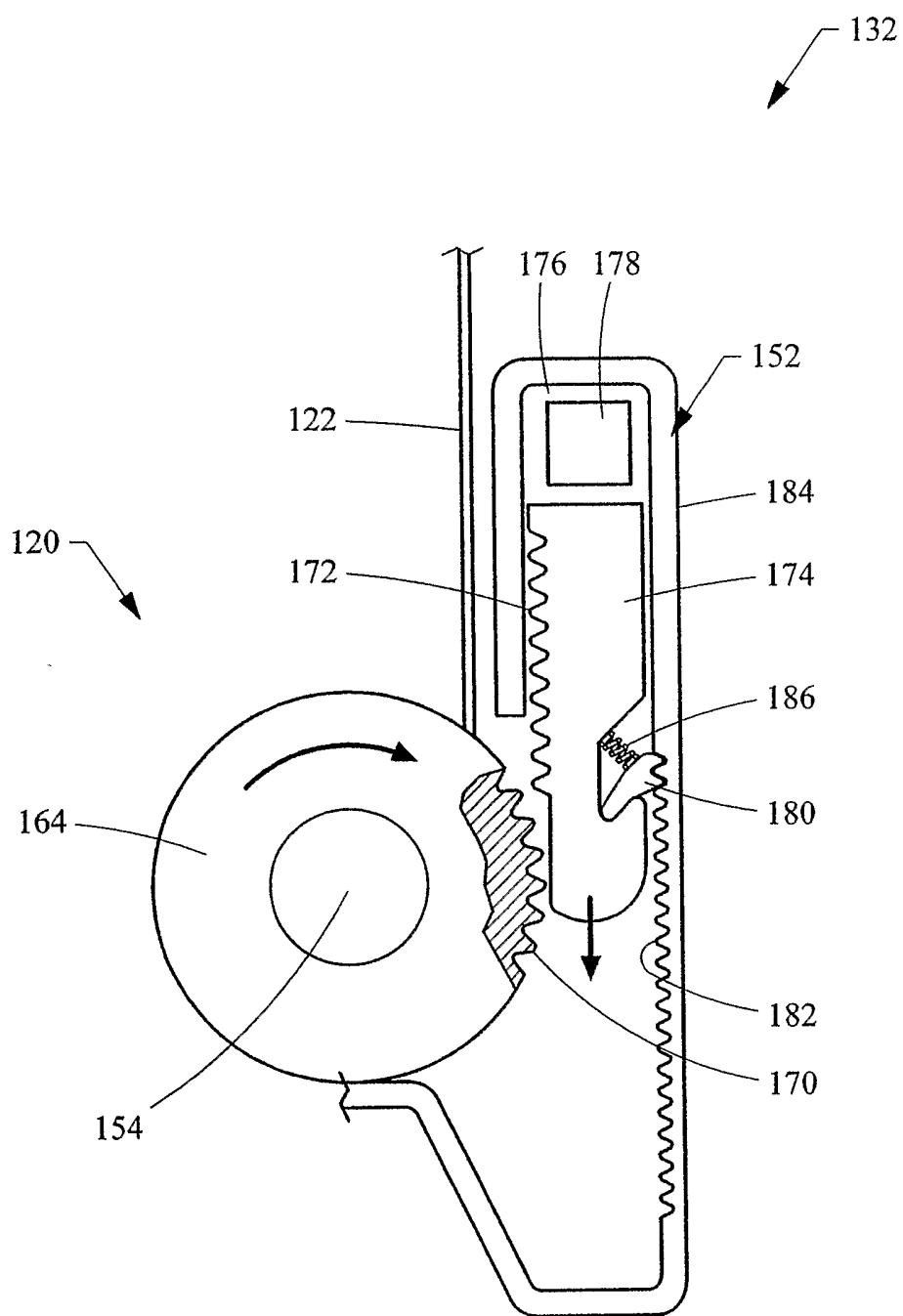


Fig. 5

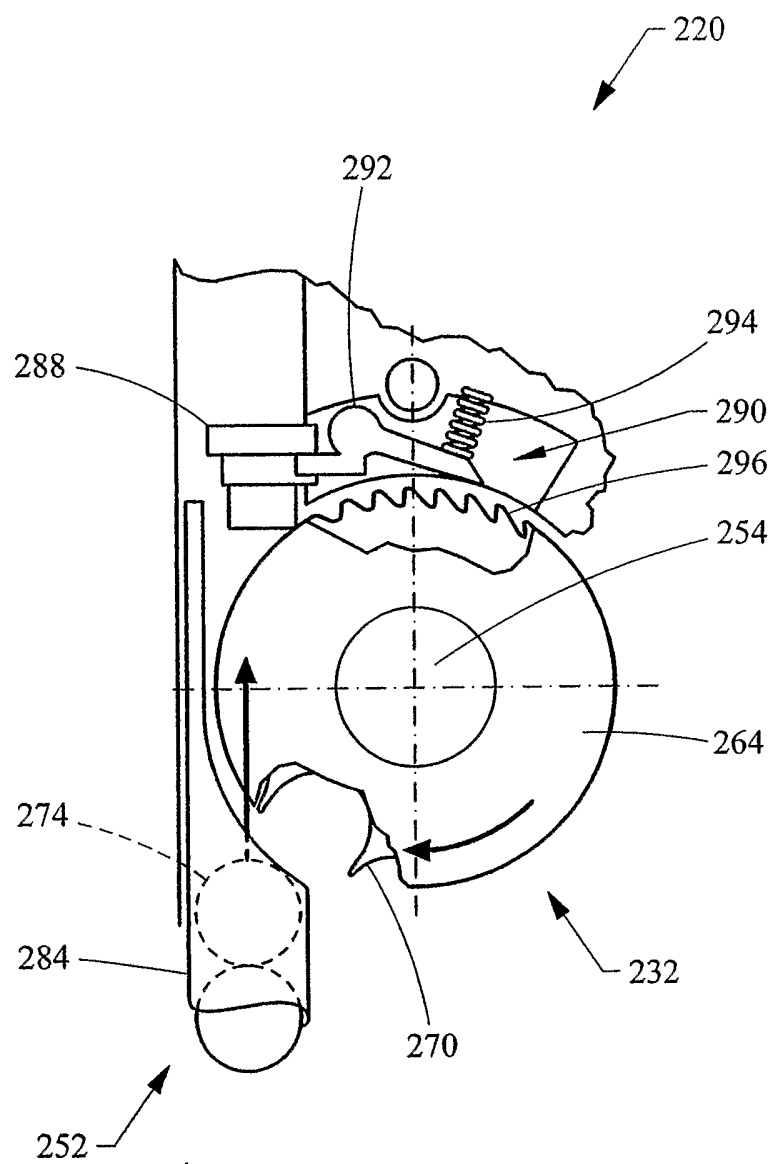


Fig. 6

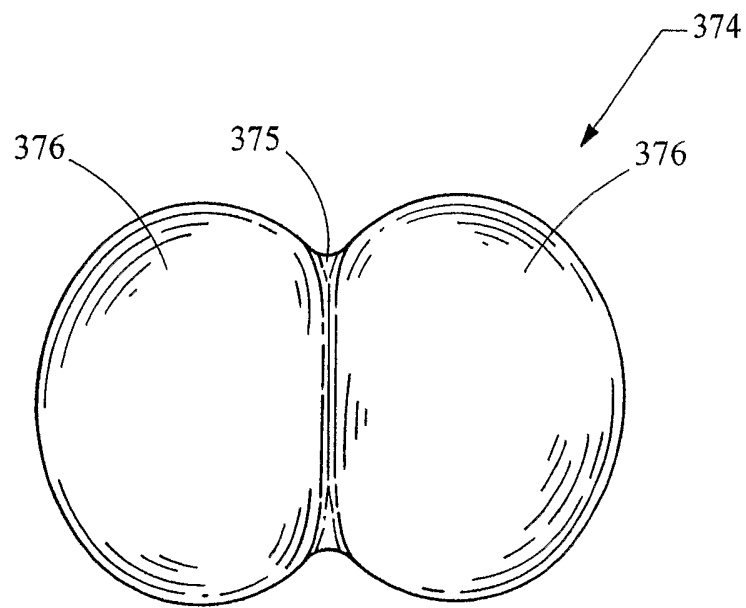


Fig. 7

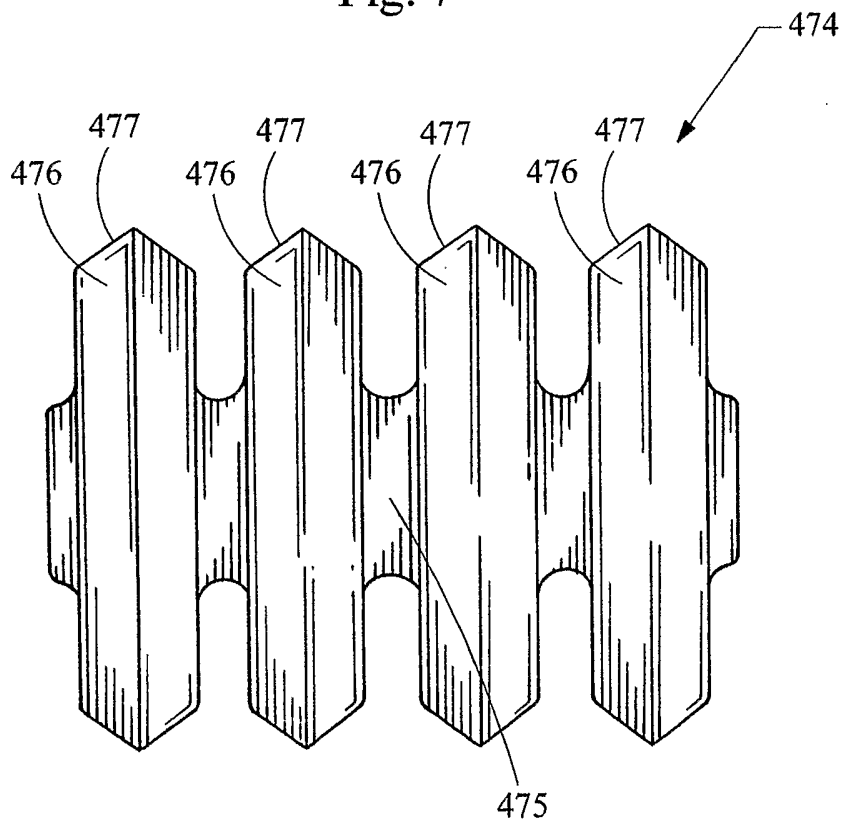


Fig. 8

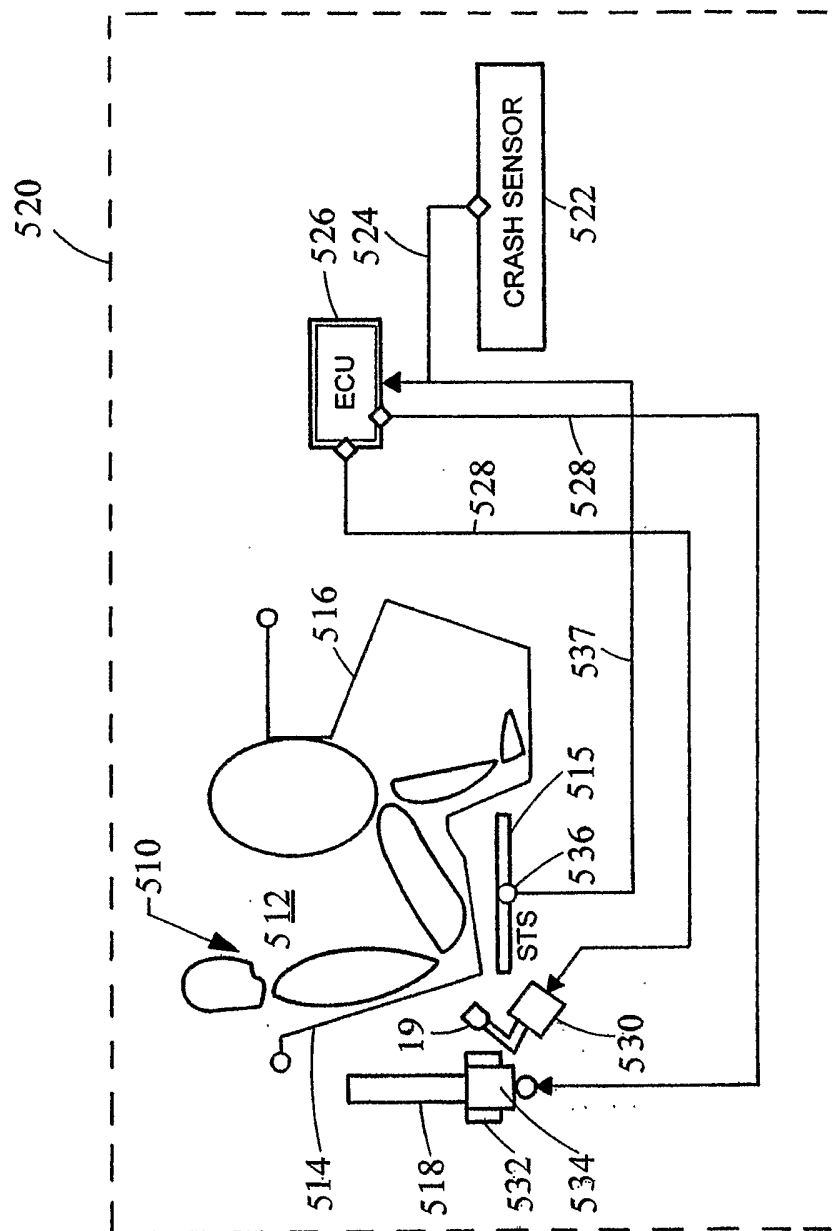


Fig. 9

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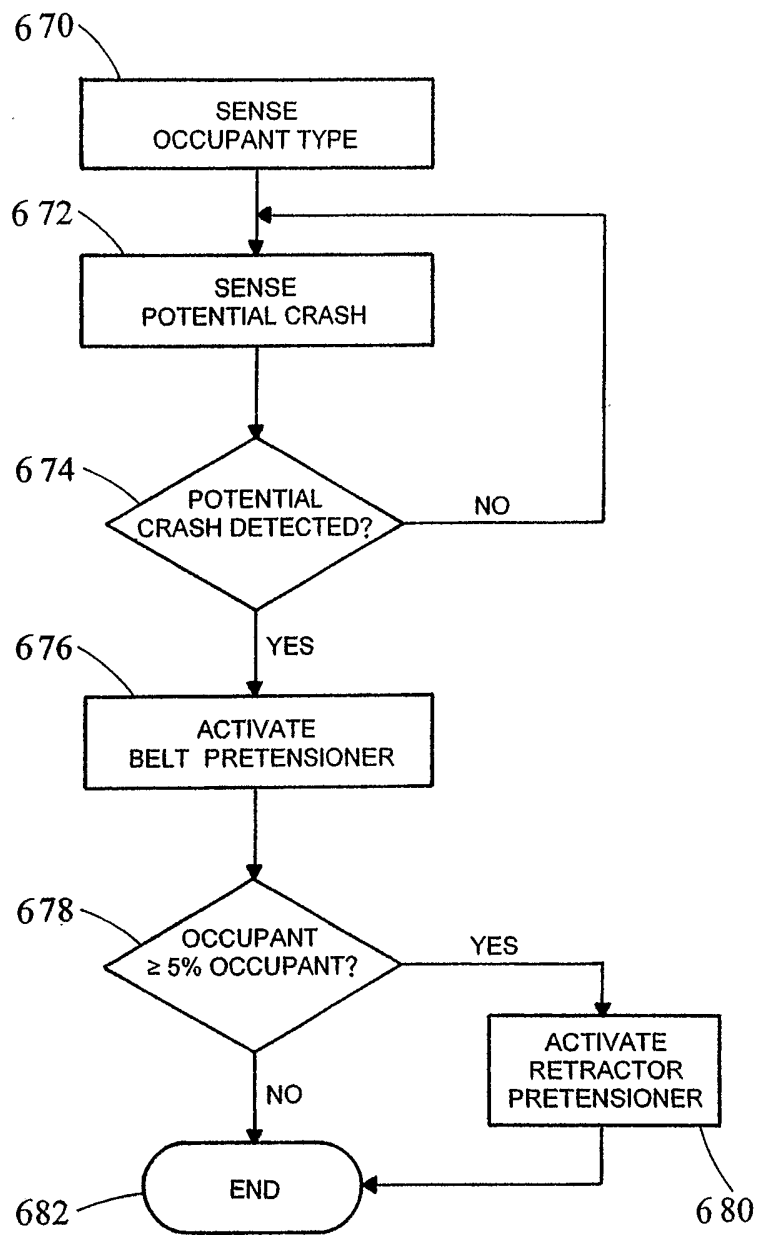


Fig. 10

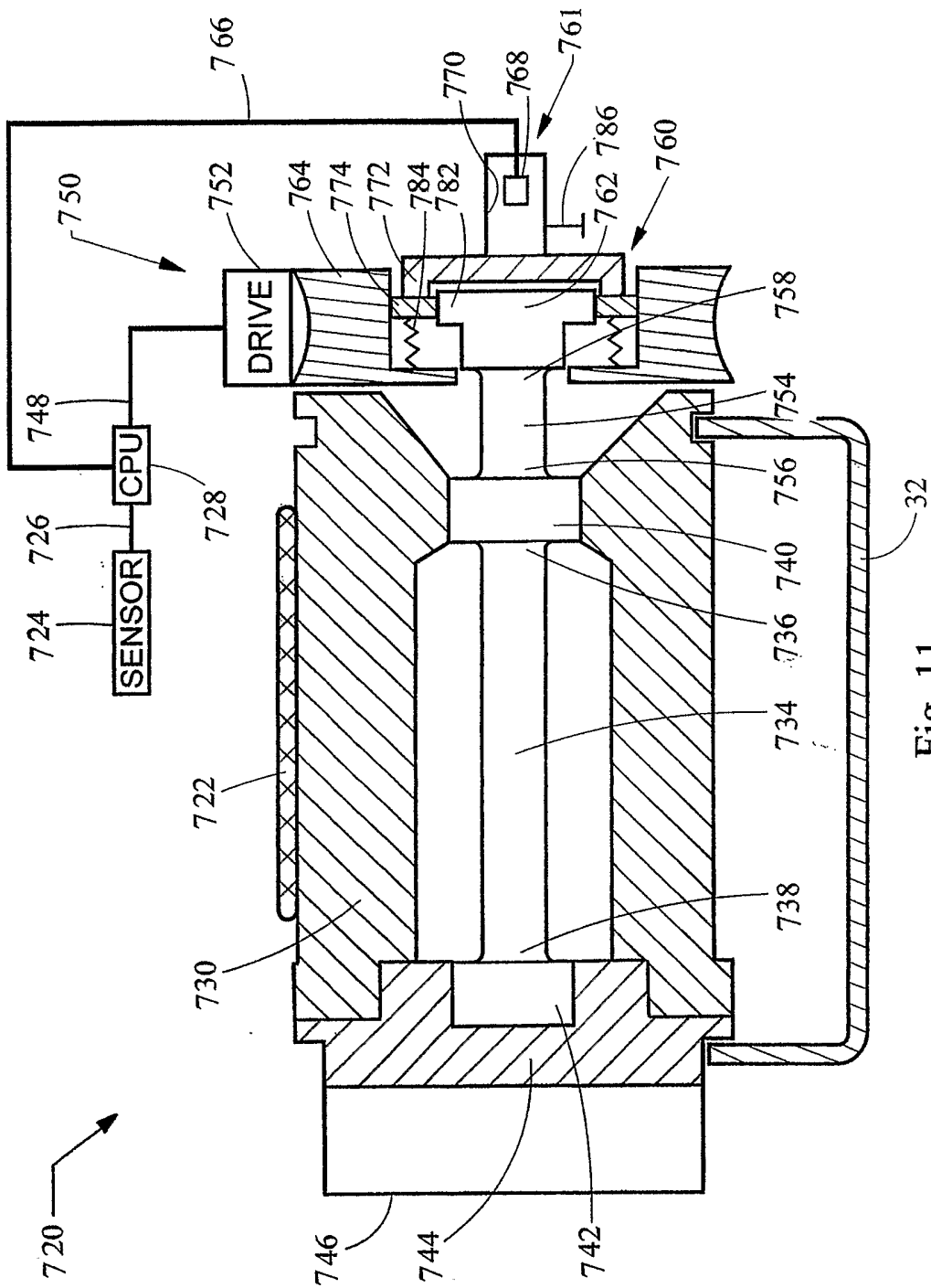


Fig. 11

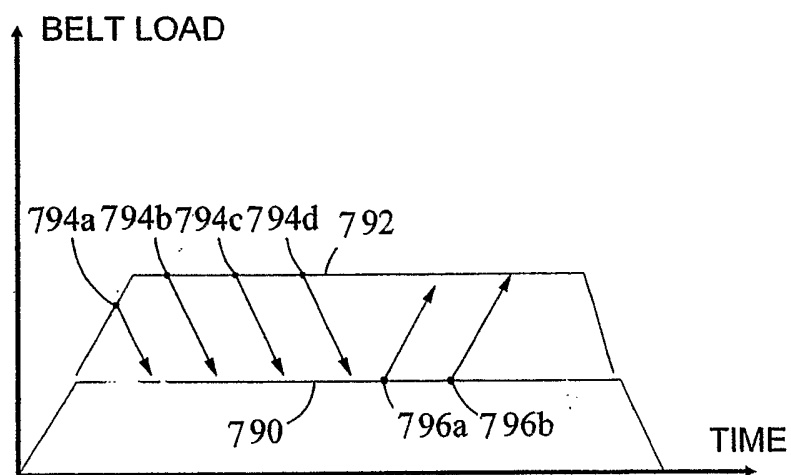
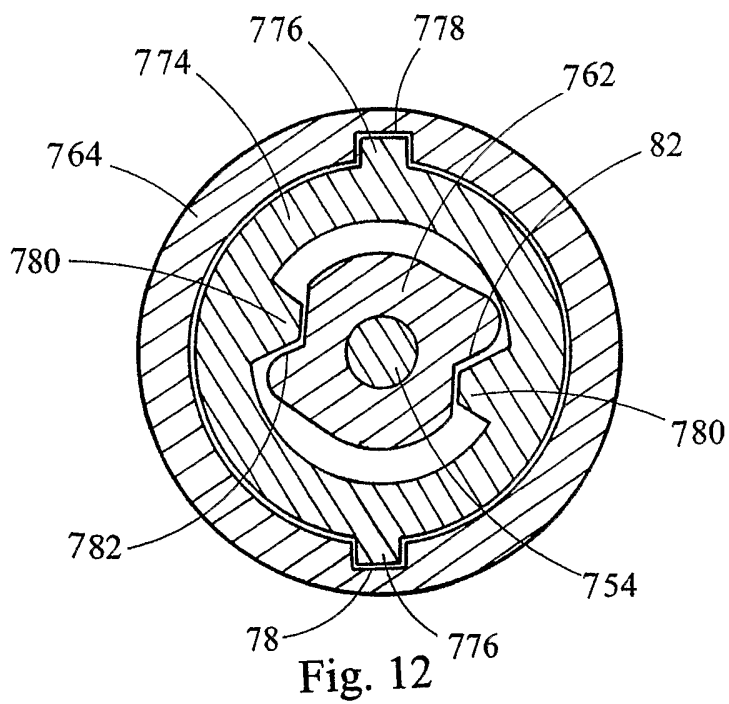


Fig. 13

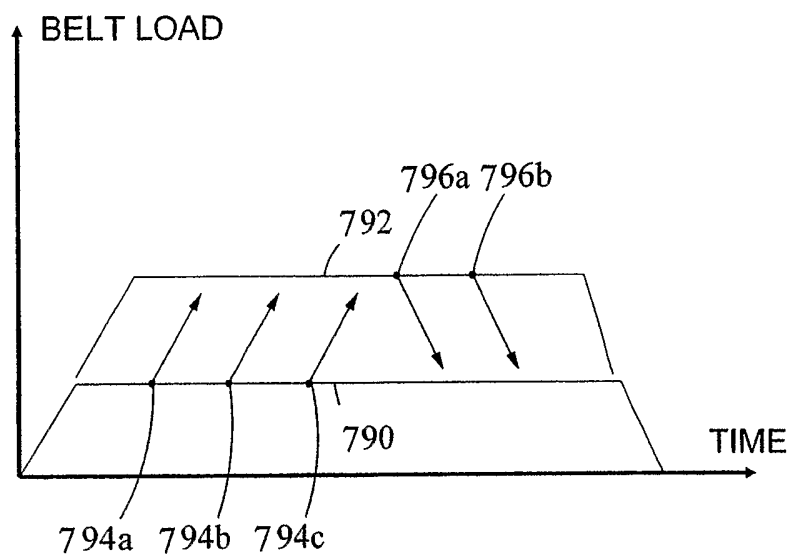


Fig. 14

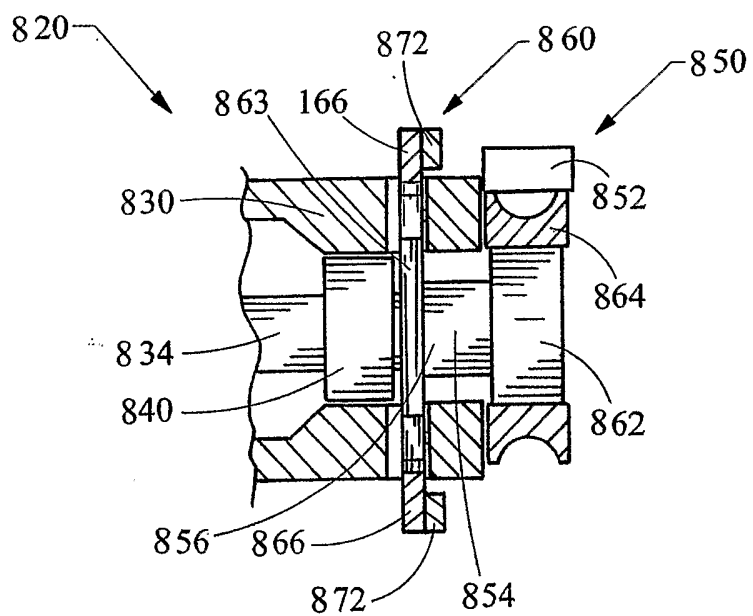
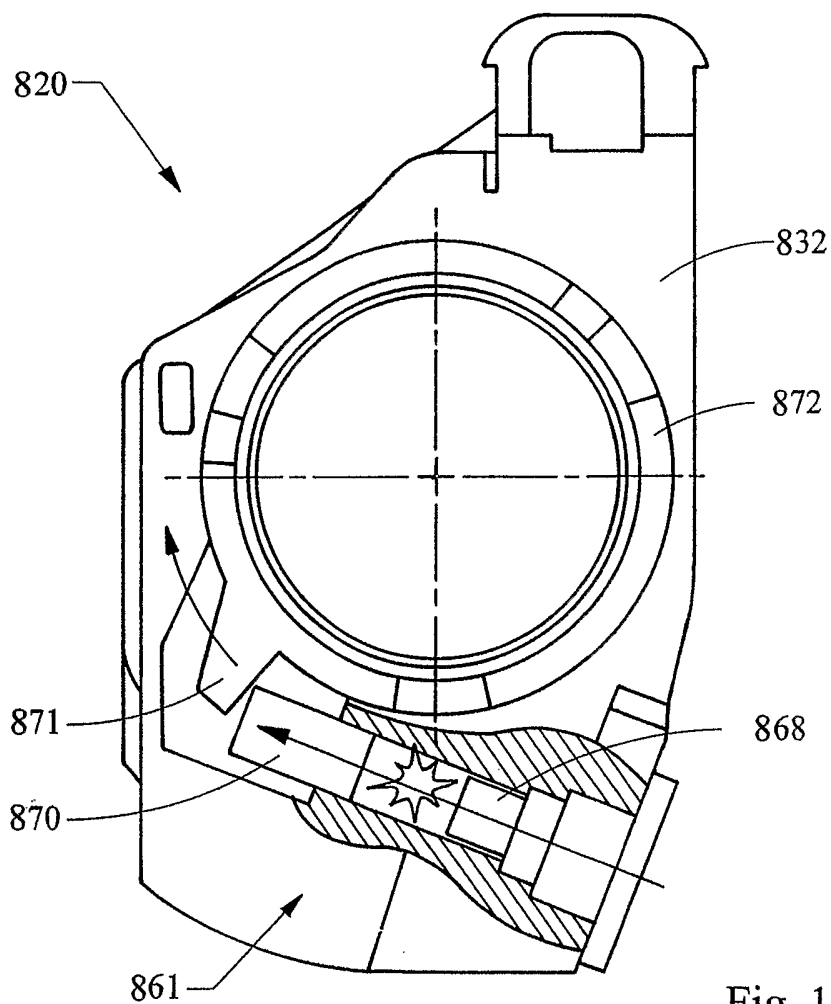
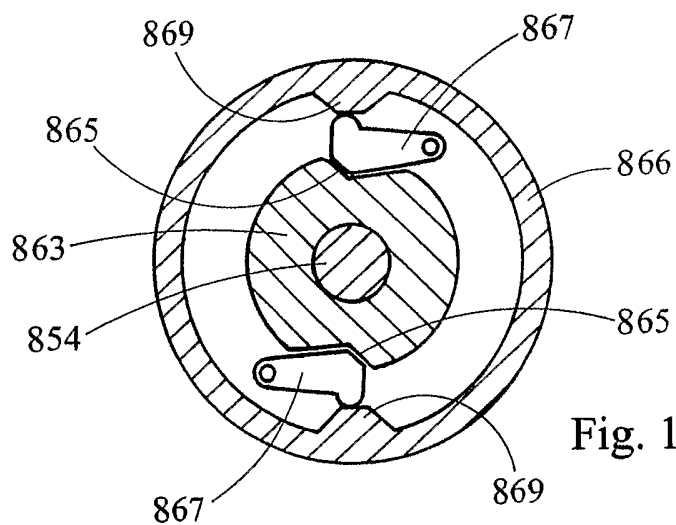


Fig. 15



INTERNATIONAL SEARCH REPORT

International application No

.../US2005/037566

A. CLASSIFICATION OF SUBJECT MATTER B60R22/46 B60R22/36 B60R21/01		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B60R		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the International search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, PAJ		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 702 326 B1 (FUJII HIROAKI) 9 March 2004 (2004-03-09) column 9, line 30 - column 10, line 41; figures 1-12	1-7, 9-15, 21-32
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : *A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family		
Date of the actual completion of the international search 7 February 2006		Date of mailing of the international search report 17/02/2006
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer Cipriano, P

INTERNATIONAL SEARCH REPORT

International application No
/US2005/037566

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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