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(54) **SERIES ELASTIC MOTORIZED EXERCISE MACHINE**

ELASTISCHE MOTORISIERTE SERIENÜBUNGSMASCHINE

APPAREIL D'EXERCICE MOTORISÉ ÉLASTIQUE EN SÉRIE

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Description

RELATED APPLICATIONS

[0001] . This Disclosure claims priority to Provisional Application entitled Elastic Torque Sensor for Planar Torsion Spring filed October 9, 2014 as application S/N 62/061815 and Concentric Arc Spline Rotational Spring filed January 1, 2015 as application S/N 62/099191.

. Field of Use

[0002] This disclosure pertains to the field of exercise machine apparatus for isokinetic, isotonic, and isometric exercises.

Background of Disclosure

[0003] Exercise machines are known. Many exercise machines utilize combinations of weight connected to a load transfer system by cables and pulleys. Others use cylindrical springs. Other apparatus utilizes the deformation of material such as steel rods to provide resistance. Other types utilize friction resistance.

[0004] Isotonic exercising. This is the exercise experienced by lifting of traditional weights. The weight remains constant regardless of the weight's position relative to the individual. This allows the individual to take advantage of the inertia of the moving weight through the horizontal position in performing an arm curl. Thus the force exerted by the individual dips as the weight moves from the bottom position (at the knees) to the waist. Momentum is created. The speed of the weight does not remain constant. Weights (Isotonic exercising) cannot change through position change. Therefore the weight does not achieve optimal strength profile.

[0005] Isokinetic. The apparatus moves a constant speed. The individual pushes or pulls against the apparatus and, in the case of the Applicant's apparatus, the individual's force is measured and recorded. The machine does all the moving at a constant speed. The force changes while the load transfer mechanism velocity remains constant.

[0006] Isometric. The load transfer mechanism is in a fixed position. The individual tries to move the mechanism. The mechanism does not move. In the Applicant's apparatus, the force applied to the stationary load transfer mechanism is sensed and recorded. This measurement is an important distinction between pressing or pulling against the stationary load transfer mechanism or other immovable object. The force changes while the load transfer mechanism position remaining constant.

[0007] Position dependent force control. The machine does not move at a constant speed. The apparatus is not controlling the speed of the apparatus. Velocity is controlled by the individual. Rather the apparatus rotational velocity is controlled to vary the resistance force in a controlled manner through the individual's range of motion.

The apparatus maintains the desired force regardless of velocity. The machine may change the amount of force applied to the individual based on the position of the load transfer mechanism within the individual's range of motion.

[0008] For the purposes of this application, "force," "torque," and "load" are used interchangeably to describe the forces applied to the user of the apparatus.

[0009] WO2007015096 describes an exercise apparatus that allows the user to perform a variety of aerobic and strength training exercises.

[0010] US2013158444 describes a robotic system for simulating a wearable device actuation delivery mechanism and the source removed from the actuation delivery mechanism that is linked to the actuation delivery mechanism by at least one cable.

[0011] US5597373 describes a system for isolating, evaluating and exercising the muscle groups of the human hand, wrist, arm and shoulder.

[0012] US2012231929 describes a strength training control device comprising a torque source and a link mechanism, wherein a S-type load cell is coupled to the first link rod and the second link rod to sense a load value.

[0013] US5015926 describes a force development system for the application of controlled variable speeds and torque forces in exercise machines utilized to strengthen and develop body muscles of an exercising person.

SUMMARY OF DISCLOSURE

[0014] . The instant disclosure teaches a combination of devices or components to create a novel exercise apparatus. Unlike many other exercise devices, the Applicant's disclosure creates a load that does not generate momentum, i.e., resistance to change in velocity. In the prior art, once the individual moves a weight, the moving weight is resistant to a change in speed. This makes continued lifting of the weight easier. The combination of weight (mass) and velocity at which the individual is moving the weights is momentum.

[0015] . The Applicant's apparatus is unique in that it combines inertiafree motion with other apparatus components including but not limited to novel torque sensors, series elastic actuator (herein after "series elastic actuator" or "SEA") and gear reducer. A series elastic actuator is defined to contain a motor, gear reducer, torsion spring, and position sensor(s). In one embodiment, the motor may be a servo motor. The inertia free movement of the apparatus means that the force generated by the apparatus (using the electric motor, gears, and rotational torsion spring) is independent of gravity. The force exerted by the device is independent of the position of the load experienced by the user.

[0016] . It will be appreciated that inertia distorts the exercise experience. It distorts the load placed on an individual's muscles leading to a less efficient workout and an increase in injury potential. It is therefore advan-

tageous to an efficient exercise session that the individual not experience inertia.

[0017] . Further, the apparatus of the Applicant's disclosure allows the individual to engage in multiple exercise modes. The individual can practice isokinetic exercising. Isokinetic exercise involves the exercise machine providing resistance to the movement of the individual. The individual can also practice isotonic exercise which involves muscle contraction in the presence of a constant load. Isometrics can also be practiced and involves the individual utilizing his/her muscles to press or pull against an immovable object. The Applicant's disclosure also allows variable force profiles over the individual's range of motion. No existing exercise machine allows all four types of exercise modes to be performed.

[0018] . The exercise machine of the Applicant's disclosure utilizes a torque sensor. The torque sensor comprises multiple components. Included is a circular torsion spring. The circular torsion spring comprises an outer ring and an inner ring. The inner and outer rings are concentric. The inner and outer rings are connected by one or more splines.

[0019] . The torque sensor also includes a position measuring sensor to detect deflection between the outer ring (output side) and the inner ring (input side) of the torsion spring. The output side of the torsion spring is connected to the load transfer mechanism. The input side of the torsion spring is connected to the rotatable shaft of a motor through a reduction gear. The apparatus detects deflection of the outer ring relative to the inner ring. The deflection can be caused by a load, e.g., an individual pulling on a bar connected by belts or similar devices in communication with the torsion spring.

[0020] . The torque measuring sensor, detecting deflection of the torsion spring, signals a servo drive motor controller or microprocessor. In response to this signal, the motor controller may cause the motor to activate. This activation can turn or rotate the motor shaft and the reduction gear. The motor shaft may rotate at variable speeds as directed by the motor controller. The motor can be a servo motor. A servo drive can contain or be in communication with a microprocessor. This motor may be referred herein as an "intelligent servo drive." The motor shaft is in communication with the gear reducer which is in communication with the inner ring (input side) of the torsion spring. The rotation of the shaft, at a speed selected by the motor controller can offset the deflection of the torsion spring. The shaft can rotate in either a clockwise or counter clockwise direction.

[0021] . The motor controller can contain embedded intelligence. The motor controller is programmable.

SUMMARY OF DRAWINGS

[0022] . The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate preferred embodiments of the invention. These drawings, together with the general description of the dis-

closure given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the disclosure.

. Figure 1 illustrates a perspective of the Series Elastic Exercise Machine (apparatus) subject of the Applicant's disclosure. Illustrated is the belt spool that is used in conjunction with a belt (not shown) attached to a load transfer mechanism (not shown) adapted for use by an individual. It will be appreciated that the load transfer mechanism can have multiple configurations, each adopted to provide a different type of exercise. Further illustrated is the series elastic torque sensor comprising two position sensors, two sets of encoders and reader for each position sensor, gear reducer, servo motor, and intelligent motor controller.

. Figure 2 illustrates a detail of the belt spool assembly, a component of the load transfer mechanism.

. Figure 3 illustrates an exploded view of additional components of the disclosure including the series elastic torque sensor, gear reducer, intelligent motor controller and servo motor. Illustrated is the continuous axis of rotation shared by all components including the spool.

. Figure 4 illustrates a perspective exploded view of the series elastic torque sensor. Illustrated is a circular mounting bracket containing a connection to the spool illustrated in Figure 1. Also shown is the outer circumferential edge of the spring output position sensor. In the embodiment shown, the sensor is transparent to light. Also shown is the torsion spring. The embodiment illustrated comprises three splines. Also shown is the spring input position sensor. In the embodiment shown, the sensor is also transparent to light. The diameters of both the input and output sensors extend past the diameter of the torsion spring. When assembled both the spring output sensor and the spring input sensor are positioned immediately adjacent to the torsion spring. The extended diameter of each position sensor can contain tick marks (not shown). Each position sensor can be utilized with two pairs of optical encoders and separate optical readers (not shown) that are mounted independent of the load path and are separately in optical communication with the spring output sensor and spring input sensor.

. Figure 5 illustrates a perspective view of the Applicant's novel elastic torsion spring which is part of the series elastic torque sensor. Illustrated in the output side, the concentric input side and three spline configured to maximize the spline length and circumferential positioning of the spline.

. Figure 6 illustrates a logic flow diagram of the operation of the encoder in conjunction with the movement of the output sensor.

. Figure 7 illustrates an encoder monitoring the sensor disk attached to the input side of the planar tor-

sion spring.

. Figure 8 illustrates a logic flow chart for torque control utilizing the optical encoder.

. Figure 9 illustrates a logic flow chart utilizing detected optical signals of movement of the input side of the planar torsion spring to compute torque force applied to the output side.

DETAILED DESCRIPTION OF DISCLOSURE

[0023] . The apparatus of the Applicant's disclosure is a Series Elastic Exercise Machine **300** illustrated in Figure 1. The apparatus includes, but is not limited to, a load transfer mechanism (including a belt spool) **299** adapted to allow an individual to move the apparatus; a series elastic torque sensor **302** including a torsion spring and position sensor disks; a programmable (intelligent) motor controller **305**; and a gear reducer **303** and a motor **304**. The motor may be a servo motor. The components of the apparatus can be mounted on a base **306**.

[0024] . The apparatus can vary the load profile throughout the range of motion utilized by the individual (through the load transfer mechanism). This pertains to the relationship between ROM (range of motion) and force. As the load changes in position relative to the user (due to the user's movement of the load) the amount of force required of the individual to be used to further move the load can automatically change. Stated differently, the relationship to the amount of required force relative to the position of the load creates a load profile. It will be appreciated that a constant load through the individual's ROM constitutes one of many types of load profiles.

[0025] . The apparatus of this disclosure is a force or velocity controllable device using a variable speed electric servo motor (having a rotating shaft), gear reduction component, torque sensor, load transfer mechanism (including a pulley or spool, belt or cable), and motor controller (having programmable embedded electronics). One function of the apparatus is to provide force for the purpose of exercise; specifically strength training. Unlike weights, the programmability of the motor controller allows the amount of force (imparted by the motor through the gear component upon the individual) to be adjusted during a workout.

[0026] . In Isokinetic training, the load mechanism moves a constant speed. The user applies resistive force against the moving load mechanism. The user's force is measured by the apparatus. The torque of the motor increases as the user resists the movement. This increase in motor force maintains constant motion of the load mechanism.

[0027] . The disclosure includes the capability to use a series elastic actuator **300** (the custom design torque sensor and planar torsion spring coupled with a gear reducer and electric motor) to control the force applied through the load transfer mechanism (comprising in part the spool **299**).

. LOAD TRANSFER MECHANISM

[0028] . The disclosure comprises a load transfer mechanism adapted to be utilized by an individual to exert force or strength on the machine subject of the disclosure. Components of the load transfer mechanism, including the rotating belt spool **301**, spool shaft **352**, and rotating spool bearing assembly **353** are disclosed in Figure 2. The load transfer mechanism (hereinafter "load transfer mechanism") contains the rotating belt spool, spool shaft, rotating spool bearing assembly and components adapted to be grasped by the individual including but not limited to a bar or handgrips and a belt attached to the bar or handgrips (not shown) and the belt spool. The mechanical load transfer component may also include but not be limited to a belt, cable, rope, chain or similar device to transfer the load to a spool. It will be appreciated that the belt component, etc. is attached to the belt spool **301** and to the bar or handgrips (not shown). The spool shaft **352** rotates on the same axis of orientation **310** shown in Figure 3. Also illustrated is the spool bearing assembly **353** that allows the spool to easily rotate under load.

[0029] . The disclosure comprises a load transfer mechanism adapted to be utilized by an individual to exert force or strength on the machine subject of the disclosure.

. SERIES ELASTIC TORQUE SENSOR

[0030] . Figure 3 illustrates a series elastic torque sensor **302**. The torque sensor components are in communication with the Load Transfer Mechanism **299**. These components share the same axis of rotation **310**. The torque sensor **302** (hereinafter "series elastic torque sensor" or "torque sensor" contains an axis of rotation shared with spool of the load transfer mechanism, reducing gear and motor. The series elastic torque sensor also contains at least one position sensor in communication with an intelligent motor controller and a planar torsion spring. (See Figure 4)

[0031] . The inner and outer rings of the torsion spring are connected by one or more splines **415**. In the embodiment shown in Figure 3, there are three splines having concentric shapes substantially parallel to the outer diameter of the inner ring. The outer ring (output side) may rotate relative to the inner ring (input side) and vice versa in response to torque force.

[0032] . The inner concentric ring (input side) may have a circular opening dimensioned to fit around the outer circumference of a rotating motor shaft or gear reducer. In one embodiment, the motor shaft and motor may have the same axis of orientation as the opening of the torsion spring. In other embodiments, the motor can be mounted at an angle to the opening of the torsion shaft. This may be advantageous for reducing space requirements.

[0033] . The torsion spring **411** may be considered a component of the series elastic torque sensor. Elastic is used here to disclose that the deflection of the torsion spring (outer or inner ring) is measured.

[0034] . This disclosure teaches a novel method of measuring the rotational degree of deflection between the output side and the input side of the torsion spring. The disclosure utilizes two spring position sensors **312**, **313** (torque sensor disks). See Figure 4. It utilizes flat circumferential plates or disks attached alternatively to the inner ring of the torsion spring or the outer ring. In one embodiment, each spring position sensor comprises a disk containing equidistant marks around the circumference of the disk. These can be tick marks. The marking designate degrees or partial degrees of the circumference. There are, of course, 360° in the circumference of each circle. These marks may alternatively be holes or apertures in the disk edge, notches in the disk edge or opaque markings on an otherwise clear disk. In another embodiment, the disk can have electromagnetic markings along the circumference.

[0035] . The series elastic torque sensor has components that measure the movement of the circumferential markings on a first and second disk. This may be a light beam emitted from a component on one side of the first disk and a light receptor located on the opposite side of the first disk. The light receptor can record a signal or the receipt of light through the clear disk or through the teeth of the serrated edged disk. It will be appreciated that the light signal will be interrupted by the light beam being blocked by the opaque markers or the solid teeth of the serrated edged disk. In another embodiment, the receptor can record an electromagnetic signal from the marking along the circumference of the disk.

[0036] . Each spring position sensor is round and has a circumference. In one embodiment, the diameter of each sensor is larger than the diameter of the planar torsion spring). This expanded circumference provides greater resolution to the position sensor and encoder components. Each disk is marked along or proximate to the circumference.

[0037] . In one embodiment, the position sensor disks can be translucent, e.g., clear plastic or polymer. The degree markings (or partial degree markings) can be opaque. An optical sensor (encoder) may be mounted on a rigid bracket independent of the rotational movement of the sensor disks or the torque load on the planar torsion spring. The encoder will shine a light beam across and through the sensor disk. The light beam will be detected by a light sensor (encoder receiver). When an opaque degree marking crosses the light path, the light sensor will detect an interruption in signal and will send an appropriate signal to a controller.

[0038] . In another embodiment, the sensor disk can have notches or teeth placed on the circumference. The encoder would detect the interruptions in light caused by the notches or teeth rotating through the light path.

[0039] . In yet another embodiment, markings can be placed on the circumference of the output side and the input side respectively. In one embodiment, the markers can be reflective and the encoder will detect the reflected light.

[0040] . An encoder attached to a separate framework (not shown) can, in one embodiment, transmit an optical signal upon the outer circumference of a spring output position sensor disk. The optical signal may be sensed by an optical reader on the opposite side of the spring output position sensor disk. The optical reader senses movement of the output side of the torsion spring. This is detected by variations of the optical signal transmitted through the disk circumference. As discussed more fully above the spring output position sensor disk may have opaque markers on the disk outer circumference. The markers, when positioned in front of the encoder block the light normally received by the optical sensor. A second (opposite) configuration is also used for the spring input position sensor. The position of each position sensor is utilized to determine the direction that torque force is being applied.

[0041] . Each optical reader device (encoder receiver) will be in communication with the intelligent motor controller. The controller will utilize the signals received from the position sensor to compute the degrees of rotation of the output side or input side (or vice versa) of the torsion spring to compute the torsion loads. It will be appreciated that the computation can be achieved upon activation of the apparatus. Therefore it is not necessary to first calibrate the degrees of rotation. See Figure 9.

[0042] . The encoder components of the spring position sensors **312**, **313** do not rotate with the servo motor, gear reducer, torsion spring and position sensors.

[0043] . Located between the first and second torque sensors is a planar torsion spring **411**. The spring position sensors and torsion spring have the same axis of rotation.

. SERIES ELASTIC ACTUATOR

[0044] . Figure 3 also illustrates the intelligent motor controller **305** beneath the gear reducer **303**. The intelligent motor controller **305** includes a microprocessor in communication with the servo motor **304** as well as a programmable user interface (not shown). One function of the intelligent motor controller is to direct motion (rotation) of the servo-motor.

[0045] . It will be appreciated that the encoder sends a signal to the intelligent motor controller regarding the amount of torque being experienced by the torsion spring. This can be the result of force transferred through the load transfer mechanism. Each combinations of light emitters and light receptors at the series elastic torque sensor **302** can measure torque deflection of either the input ring or the output right. When deflection is detected, a signal is sent to the intelligent motor controller **305**. The program of the motor controller can provide instructions to the servo motor **304**.

[0046] . It will also be appreciated that the torque transmitted through the load transfer mechanism causes the movement of the planer torsion spring, which in turn is detected by the torque sensor reader and communicated to the motor controller.

[0047] . The load or force created by the rotating motor as modified by the gear reducer also is transferred through the series elastic torque sensor (including the torsion spring). Deflection of the input side of the torsion spring will cause a signal to the intelligent motor controller.

[0048] . The operation of the motor controller (and the resulting controlled operation of the motor and gear reduction) can continuously vary the load profile throughout the range of motion utilized by the individual (through the load transfer mechanism). This pertains to the relationship between ROM (range of motion) and Force. As the load transfer device changes in position relative to the individual (due to the individual's movement of the load) the amount of force required of the individual to be used to further move the load transfer device changes. Stated differently, the relationship to the amount of required force relative to the position of the load creates a load profile.

[0049] . Figure 3 also illustrates that the servo motor **304**, gear reducer **303**, and series elastic torque sensor **302** share a common axis of rotation **310**. It will be appreciated that this same axis of rotation extends through the spool shaft in Figure 2.

[0050] . Figure 4 illustrates a detailed view of the components of the series elastic torque sensor **302** Shown is the rotating plate **314** which is part of the load path. Attached is the spring output position sensor **312**. In the embodiment illustrated, it comprises a transparent circular disk. The diameter of the disk is larger than the diameter of the torsion spring **411**.

[0051] . The torsion spring is illustrated having 3 splines **415**. On the opposite side of the torsion spring from the spring output position sensor is the spring input position sensor **313**. Also shown is the axis of rotation **310** extending from the servo motor (**304** on Figure 3) to the spool shaft (**352** on Figure 2).

[0052] . Figure 5 illustrates an example of a planar torsion spring **411** utilized by the Applicants. The axis of rotation of the torsion spring is the same as the axis of rotation of the larger diameter position sensor. This axis of rotation is shared with the outer ring (the output side) **410** and the inner ring (the input side) **420**. The axis of rotation passes through point **140** of the open center section of the spring.

[0053] . The outer spring output is in communication with the load transfer component via a rotating plate **314** and described in paragraph [0056]. The torsion spring may be either of harmonic or planetary design. In one embodiment, the Applicant utilizes a unique planetary torsion spring design

[0054] . The Applicant's torsion spring utilizes 3 splines **415**. The spring comprises a planar surface. The plane extends along the x and y axis. The spring has a radius in the x and y axis. The output side is concentric about the input side. The input side and output side share the same axis of rotation (See Figure 2, items **140** and **310**. The axis of rotation and longitudinal axis and spring thick-

ness **435** are in the z direction.

[0055] . The planar torsion spring comprises an inner ring **420** nested within a larger diameter outer ring **410**. Stated differently, the inner ring is positioned concentrically within the diameter of the outer ring. The torsion spring has a planar shape.

[0056] . The concentric inner and outer rings are joined together by one or more splines **415**. The splines can form elongated concentric arcs **431** surrounding the exterior diameter of the inner ring. The design of the spline can be opposite the design of a spoke between an outer rim and inner hub. It will be appreciated the spoke will extend from the inner hub in a radial straight direction to the outer rim. It will be appreciated that the elongated concentric arc (serpentine) of the Applicant's design permits the greater deflection of the spline with lower stress. The Applicant's design achieves this improvement by the longer load path formed of the elongated design of the concentric arc splines. It will be further appreciated that the spline can be deflected or deformed by the rotation of one ring relative to the other ring. Stated differently, by deformation of the splines, one ring may be rotated relative to the other ring.

[0057] . With fewer splines, each spline can be designed longer to achieve a wider range of stiffness, but a lower maximum achievable stiffness. With fewer splines, each spline can be designed to have a longer extended path **430** between the inner ring and the outer ring. The thickness of the spline may be varied through the elongated length.

[0058] . An alternate description of the torsion spring **411**, a spring comprising fabricating a first outer ring **410**, fabricating a second inner ring **420** which is positioned within the first outer ring and possessing a same axis of one or more splines **415** and extending the spline to a maximum length relative to the circumference between the first outer ring and second inner ring **431**, fabricating the spline with the desired number concentric arcs between the inner circumference of the first outer ring and the outer circumference of the second inner ring and positioning the first outer ring, the second inner ring and the spline in the same plane. Each spline is connected by a tab **433** to the outer ring **410** and the inner ring **420**.

[0059] . The advantages of the Applicant's construction includes increased strength and flexure of the spring. With fewer splines, each spline can be designed longer to achieve a wider range of stiffness, but a lower maximum achievable stiffness. With fewer splines, each spline can be designed to have a longer extend path between the inner ring and the outer ring. The thickness of the spline may be varied through the elongated length.

[0060] . The Applicant's planar torsion spring illustrated in Figure 5 may be comprised of standard steel alloys e.g., 17-4PH stainless steel. This stainless steel utilized in the Applicant's design can achieve the same stiffness and strength of more expensive or more difficult to work with such as custom 465 stainless steel or maraging steel. Also, the spring illustrated in Figure 5 can achieve

a wider range of spring stiffness in other spring designs. The Applicant's torsion spring can be made of various materials including composite materials. The planar torsion spring is preferably made of metal such as steel. In some embodiments it can be made of maraging steel, a steel composite having a high yield strength.

[0061] . Further, the Applicant's novel spring architecture reduces stress concentration by distributing the load more predictably and evenly. This means that the peak stress in the material is less with the new design given a size and stiffness target. The spring geometry (Figure 5) illustrates a larger load path. It will be appreciated that the greater load path allows the stress created by spring deflection to be spread over a greater area, resulting in smaller and less consequential stress concentrations. The Applicant's spring design 411 shown in Figure 5 allows the use of more standard alloys to get the same max load rating and stiffness.

[0062] . It will of course be appreciated that the utility of the Applicant apparatus 300 subject of this disclosure is not dependent upon the Applicant's torsion spring design 411 illustrated in Figure 5.

[0063] .

[0064] . The apparatus 300 of this disclosure is a force or velocity controllable device using a variable speed electric motor (having a rotating shaft), gear reduction, torque sensor, spool, belt, and motor controller (having programmable embedded electronics). All are on the same axis of orientation 310. The main purpose of the apparatus is to provide force for the purpose of exercise; specifically strength training. Unlike weights, the programmability of the machine allows for the amount of force imparted on the user to be adjusted during a workout. The disclosure includes the capability to use a series elastic actuator (the custom design torque sensor and planar torsion spring) to control the force applied to the load transfer mechanism. This apparatus can maintain constant force being transferred to the user via the load transfer mechanism.

[0065] . This disclosure incorporates by reference herein US Patent No. 5,993,356 issued November 30, 1999 to Randle M. Houston et al. in its entirety.

[0066] . Also taught by the Applicant in its disclosure is the novel use of a series elastic actuator (SEA). An SEA consists of the motor 304, gear reducer 303, torsion spring 411, and position sensor(s) 312. In one embodiment, the motor may be a servo motor. The components are connected as follows: motor attaches to gear reducer, gear reducer attaches to a torsion spring wherein two position sensors are respectively attached to the input and output rings of the torsion spring. Each position sensor 313 of the series elastic actuator can include encoders that signal the motor controller of movement of the torsion spring. The encoders are not in the load path. The motor controller 305 utilizes the signal from the light receptor component of the encoder to measure the deflection of the spring to calculate torque/force.

[0067] . It will be appreciated that the prior art utilizes

an electric motor. An SEA utilized by the Applicant allows direct control the torque seen on the output or input side of the torsion spring. This direct control of torque reduces the reflected inertia of the motor. This allows the apparatus of the Applicant to use a gear reducer 303. A gear reducer normally significantly magnifies the reflected inertia of the motor. (Motor inertia seen at the output of a gear reducer is equivalent to the motor inertia multiplied by the gear ratio squared).

[0068] . There have been several problems with motorized strength equipment in the past. One problem has been that the control methods for the motor did not contemplate or adequately address the measurement of torque/force, resulting in the motor having relatively large reflected inertia. This large inertia causes problems unaddressed by patent 5,993,356 incorporated herein by reference in its entirety. This problem (large reflected inertia) also causes problems with other devices. Such problems included a non-smooth motion or difficulty in changing directions of movement of the load transfer mechanism.

[0069] . The Applicant solves the problems of paragraphs [00076] by using the series elastic torque sensor on the output side of the gear reducer, so that the output torque is controlled directly. This control removes the past practice of inferring the output torque. The disclosure also teaches controlling torque rather than velocity. Change in direction of movement (rotation) can occur without difficulty since the motor controller can selectively ignore velocity and direction.

[0070] . It should be appreciated that the series elastic torque sensor performs all functions of commercially available torque sensors and is considerably less expensive than commercially available torque sensors. Commercial suppliers of torque sensors include Futek, and Interface T27. The Interface torque sensor T27 is listed at \$9,045.00. The Futek torque sensor FSH02059 is listed at \$3,630.00. The cost of the Applicant's series elastic torque is \$300.00.

[0071] . The Applicant's disclosure also teaches that it is advantageous to measure torque rather than linear force. As discussed above, the Applicant measures torque using a combination of a torque sensor (including a torsion spring) and a motor controller.

[0072] . Linear force is commonly measured by using an inline load cell. Load cells are commercially available devices that measure stretching or compressive applied loads. One example of a commercially available load cell is available from Futek at www.futek.com/product. However load cells are expensive and subject to wear or deterioration in various ways. Load cells therefore require replacement. It should be noted that the load cell is part of the load chain and moves with the load transfer mechanism. This movement complicates maintaining an effective electrical connection to other components of the apparatus.

[0073] . Another method of measuring torque is a motor electric current measurement device. As stated this can

be a method of torque control. However this method has disadvantages including but not limited to noise and slow operation. A motor electric current measurement device is not suitable for the dynamic force control needs of the Applicant's apparatus.

[0074] . The Applicant's adaption of a series elastic actuator (SEA) solved both problems. It is more reliable than the load cell based force measurements and more accurate than current sensor based measurements. It also allows smooth motion of the load transfer mechanism and the ability of the motor shaft to change directions.

[0075] . As stated above in paragraph [00074] a series elastic actuator consists of a motor, gear reduction, spring, and position sensor(s). The components are connected as follows: motor attaches to gear reducer, gear reducer attaches to spring, a position sensor or position sensors is/are used to measure the deflection of the spring to infer torque/force. The series elastic actuator is the force generator system of the Applicant's apparatus.

[0076] . Another problem experienced in the prior art has resulted from using gear reducers. As stated previously, the inertia of the motor is dramatically increased when a gear reducer is used. This has resulted in gear reduction components not being used. This has resulted in devices having inferior control of force. Previously, devices utilizing gear reducers move too slowly to be suitable for exercise machines. (Geared devices have previously used only for isokinetic workouts). For example the device described in patent 5,993,356 does not utilize gear reduction components. This is attributed to the problems with force control in the presence of a large motor inertia. It will be appreciated that a motor driven machine that does not use a gear reduction component is either very limited in the ability to generate or control force or uses a very large motor. As explained below, the Applicant's apparatus utilizes a smaller motor.

[0077] . In regard to comparative motor size, the Applicant's actuator (motor plus gear train has a mass of 11.5 kg. The actuator produces a peak torque of 154 Nm. An equivalent direct drive motor without a gear train that provides equivalent torque has a mass of 49 kg and is more expensive. Note the Applicant compared its motor/gear-train combination with a motor from the same manufacturer that provides the same peak torque as the Applicant's combination. The Applicant's motor is supplied by Kollmorgen, Radford, Virginia.

[0078] . As discussed in paragraphs [00075], [00083] and [00084], the Applicant's apparatus utilizes a gear reducer. In the current embodiment, the ratio of the gear reducer is 10:1. The Applicant's use of a gear reducer amplifies the torque of the motor. This allows the Applicant to use a geared motor that can be 20-25% of the mass of an equivalent direct drive motor. The cost savings and mass reduction are substantial.

[0079] . The Applicant's utilization of an SEA also achieves solution or mitigation of the following deficiencies experienced in the prior art. The deficiencies solved

by the use of Series Elastic Actuator (SEA) include but are not limited to reflected inertia range of forces and speeds (power) that can be generated by a physically smaller motor. The SEA is more reliable than a load-cell based upon force measurements and more accurate sensor based measurements. The addition of the series elastic element (torsion spring) acts as a passive mechanical filter to smooth out high frequency vibration from the motor.

[0080] . The Applicant's use of a series elastic actuator SEA significantly improves isotonic force control (constant muscle force) performance while still maintaining other modes of operation such as isokinetic (constant muscle and joint speed) and isometric (constant muscle and joint position). It also allows for variable force profiles.

. MOTOR CONTROLLER

[0081] The motor controller of the Applicant's device is fully programmable making it independent of the kinematic relationships that exist in traditional weight machines. In other words, the force is completely independent of the position within the ROM. The motor controller (hereinafter entitled "intelligent motor controller") also contains embedded intelligence, e.g., microprocessor and intelligent servo drive, capable of operating algorithms of the motorized torque controllable exercise machine apparatus

[0082] . The intelligent motor controller can also collect data, including the strength utilized by the user. The data will be recorded on the user interface computer and then sending it over the Internet to the Applicant's servers. The data can be stored in the cloud. The microprocessor of the intelligent motor controller collects the data and sends it to the user interface computer, but in one embodiment, the intelligent motor controller does not store the data.

[0083] . The apparatus **300** measures two positions to calculate torque. The two positions are measured by the spring output position sensor **312** and the spring input position sensor **313**. The position sensors signal the motor controller **305** of the respective positions of the torsion spring input **420** and output **410**. The intelligent motor controller utilizes changes in the respective positions to measure movement. Utilizing the spring constant, the torque (force) applied to the torsion spring is calculated. The device of the invention can record both force and position data.

[0084] . Figure 6 illustrates a logic flow diagram of the operation of the encoder in conjunction with the movement of the spring output position sensor. The encoder emits a signal at a rate of at least 10 kilohertz (10,000 cycles/sec). In one embodiment the signal is a pulse of light. The light pulse encoder monitors the position of the output side (Step 1) of the torsion spring. In another embodiment, the light source is continuous. If the optical receiver of the encoder detects a change in signal, either an interruption of the light signal received by the light

receiver or receipt of a light source, the optic receiver of the encoder detects rotational movement of the output side. A signal will be sent to the computer processor of the intelligent motor controller (Step 2).

[0085] . The number of light signal interruptions can be detected by the encoder optic receiver and counted by the motor controller (Step 3). The number of interruptions correlates to the number of tick marks on the circumference of the sensor disk attached to the output side. The number of ticks correlates to the distance of the circumference traversing across the encoder optic receiver. This correlates to the number of degrees of the arc segment. The length of the arc (angular position) is calculated by the computer processor of the motor controller. Knowing the spring constant, the amount of force experienced by the output side can be calculated (Step 4). The motor controller can send a responsive signal to the motor to generate force.

[0086] . Simultaneously, a separate optic output component of the encoder and the encoder optic receiver monitors the input side of the torsion spring (Step 5). If movement is detected, the receiver submits a signal of the number of light interruptions (or light reflections if reflective markers are used) to the motor controller and the processor calculates the angular position and the force based upon the amount of movement and spring constant (Step 6). The intelligent motor controller can send a responsive signal to the motor.

[0087] . The angular positions of both the output **410** and input side **420** of the torsion spring **411** are measured independently by spring input position sensor **313** and the spring output position sensor **312**. The two angles (angular position of the input and output side of the torsion spring) are differenced and multiplied by the spring constant. The result of this calculation gives torque. The torque is then used at multiple kilohertz as feedback for a torque controller. This computation is performed by the intelligent motor controller **305** that contains a computer processor.

[0088] . The intelligent motor controller can compare the calculated measurements of force on the output side and on the input side of the torsion spring. (Step 7)

[0089] . The process is repeated for the next time interval. In the preferred embodiment, the time interval is at least $1/1 \times 10^{-5}$ second. (Step 8) If movement is detected, the movement is measured from the previous read position (Step 3). The force is calculated based upon the movement to the new position. (Step 9) Steps 3 through 7 are repeated.

[0090] . Figure 6 illustrates another embodiment of the disclosure. Here, an encoder monitors the sensor disk attached to the input side of the planar torsion spring. (Step 1). The sensor detects whether the input side moves (Step 2).

[0091] . In a preferred embodiment, an encoder transmits a light signal through the sensor disk attached to the input side of the planar torsional spring. The light is transmitted through the translucent disk to an encoder receiver

on the opposite side of the disk. As discussed previously, the circumference of the disk is marked with opaque tick marks. These marks interrupt the light signal as the input side moves through the light signal. The interruptions are detected by the encoder receiver. The receiver transmits a signal of the interruption to the computer processor. The computer processor can calculate the distance rotated by the disk.

[0092] . In step 3 the computer processor computes the rotational movement based upon the signals received from the encoder receiver. Using the known spring constant, the computer processor calculates the force experienced by the input side (Step 4). Simultaneously, signals from the encoder monitoring the sensor disk attached to the output side can be used by the computer processor to ascertain whether the output side has moved (Step 5).

[0093] . If movement is detected, the amount of rotation is calculated by the computer processor based upon the signals received from the encoder receiver (Step 6). The amount of force experienced on the output side can be calculated based upon the amount of deflection and the spring constant. This computed force can be reconciled with the value computed in Step 4 above.

[0094] . In an embodiment, the computer processor can compute the amount of offset force that could be generated by a torque force generator (e.g. motor).

[0095] . It will be appreciated that the spring output/input position sensors (encoder sensors), are not affixed to the planar torsion spring. These sensors, in communication with the computer processor or microprocessor of the intelligent motor controller, are independently mounted to the apparatus and are not in the load path experienced by the output side or input side of the torsion spring.

[0096] . Alternate sensor mechanisms can include a resolver, i.e., an analog encoder that converts an angle into a voltage level that can be read by an analog digital converter (ADC), or an Absolute Position Sensor (APS) which provides an exact angle based on a fixed zero point. In one embodiment, the sensor utilizes an incremental encoder. The incremental encoder requires a startup step of positioning the output and input sides each time the spring is activated.

[0097] . As stated the apparatus of the Applicant's disclosure, the apparatus contains an intelligent motor controller.

[0098] . Figure 7 illustrates a logic flow diagram for utilizing detected movement of the spring position sensor disks by the encoder and transmission of signals to the programmable computer processor or microprocessor of the intelligent motor controller for calculation of torque.

[0099] . Figure 8 illustrates a logic flow diagram utilizing detected optical signals of movement of the input side of the planar torsion spring to compute torque force applied to the output side.

[0100] . Figure 9 illustrates the use of the encoders to determine torsion spring torque.

[0101] . This disclosure is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the manner of carrying out the subject matter of the disclosure. It is to be understood that the forms of the subject matter of the disclosure herein shown and described are to be taken as the presently preferred embodiments. As already stated, various changes may be made in the shape, size and arrangement of components or adjustments made in the steps of the method without departing from the scope of this disclosure. For example, equivalent elements may be substituted for those illustrated and described herein and certain features of the disclosure may be utilized independently of the use of other features, all as would be apparent to one skilled in the art after having the benefit of this disclosure.

Claims

1. A motorized torque controllable exercise machine apparatus (300) comprising:

1) a series elastic actuator, comprising:

1.1) a series elastic torque sensor (302), comprising:

1.1.1) a torsion spring (411), having an input side and an output side;

1.1.2) at least one spring position sensor (312, 313), configured to measure a deflection of the torsion spring (411);

1.2) a geared rotating variable speed motor, comprising a motor (304) attached to a gear reducer (303);

1.3) a programmable motor controller (305);

2) a load transfer mechanism (299), comprising a pulley or spool;

wherein the at least one spring position sensors (312, 313) is in communication with the programmable motor controller (305); and

wherein the geared rotating variable speed motor is connected with the input side of the torsion spring (411), and the load transfer mechanism (299) is connected with the output side of the torsion spring (411).

2. A motorized torque controllable exercise machine apparatus (300) according to claim 1, wherein

a) the series elastic torque sensor (302) is in communication with

(i) a shaft of the geared rotating variable speed motor;

(ii) at least one planar torsion spring position sensor (312, 313) in communication with a microprocessor;

b) the microprocessor being in communication with an intelligent servo drive;

c) the servo drive being in communication with the geared rotating variable speed motor;

d) the shaft of the geared rotating variable speed motor attached in an input side (420) of the series elastic torque sensor (302); and

e) the microprocessor controlling a rotation of the shaft of the geared rotating variable speed motor.

3. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a microprocessor controlling the speed of the rotation of the shaft of the geared rotating variable speed motor.

4. The motorized torque controllable exercise machine apparatus (300) of claim 2 wherein the microprocessor responds to force applied to the load transfer mechanism (299).

5. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a microprocessor controlling the force created by the rotation of the shaft of the geared rotating variable speed motor.

6. The motorized torque controllable exercise machine apparatus (300) of claim 4 wherein the microprocessor controlling the force of the rotation of the shaft of the geared rotating variable speed motor responds to the speed applied to the load transfer mechanism (299).

7. The motorized torque controllable exercise machine apparatus (300) of claim 1 wherein signals from the torque sensors (312, 313) comprise input to a microprocessor to control the action of the shaft of the geared rotating variable speed motor.

8. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a gear reducer (303) for the geared rotating variable speed motor.

9. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a planetary gear reducer (303) for the rotating variable speed motor.

10. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a spur type gear reducer (304) for the rotating variable speed motor.

11. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a helical type gear reducer (303) for the rotating variable speed motor.
12. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a cycloidal gear reducer (303) for the rotating variable speed motor.
13. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a harmonic drive gear reducer (303) for the rotating variable speed motor.
14. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a series elastic torque sensor (302).
15. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a planar torsion spring (411).
16. The motorized torque controllable exercise machine apparatus (300) of claim 1 wherein the load transfer mechanism (299) comprises a belt with an attachable first end and a second end attached to a spool.
17. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising an interface device.
18. The motorized torque controllable exercise machine apparatus (300) of claim 17, wherein the interface device is in communication with a microprocessor.
19. The motorized torque controllable exercise machine apparatus (300) of claim 1 wherein the apparatus performs isokinetic exercises.
20. The motorized torque controllable exercise machine apparatus (300) of claim 1 wherein the apparatus performs exercises in an isotonic mode.
21. The motorized torque controllable exercise machine apparatus (300) of claim 1 wherein the apparatus performs exercises in an isometric mode.
22. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a motor controller containing embedded intelligence to change the amount of force applied to the load transfer mechanism (299) based on position of the load transfer mechanism (299).
23. The motorized torque controllable exercise machine apparatus (300) of claim 1 further comprising a programmable motor controller (305) containing embedded intelligence to control alternately the speed or force generated by the motor (304) in response to force or speed variable inputs from the load transfer mechanism (299).
24. A method for producing variable loads in response to force or speed of movement on a motorized torque controllable exercise machine apparatus (300), comprising steps of:
- 1) providing a series elastic actuator, comprising:
 - 1.1) a series elastic torque sensor (302), comprising:
 - 1.1.1) a torsion spring (411), having an input side and an output side;
 - 1.1.2) at least one spring position sensor (312, 313), adapted to measure a deflection of the torsion spring (411);
 - 1.2) a geared rotating variable speed motor, comprising a motor (304) attached to a gear reducer (303);
 - 1.3) a programmable motor controller (305);
 - 2) providing a load transfer mechanism (299), comprising a pulley or spool;
- wherein the at least one spring position sensors (312, 313) is in communication with the programmable motor controller (305); and wherein the geared rotating variable speed motor is connected with the input side of the torsion spring (411), and the load transfer mechanism (299) is connected with the output side of the torsion spring (411).
25. A method according to claim 24, comprising the steps of:
- a) inputting a load into the load transfer mechanism (299);
 - b) transferring the load to the series elastic torque sensor (302) containing a torsion spring (411);
 - c) communicating a spring deflection torque signal to the programmable motor controller (305);
 - d) instructing the movement of the motor (304) by the programmable motor controller (305);
 - e) adjusting the movement of the motor (304) through the gear reducer (303);
 - f) transferring force to the series elastic torque sensor (302); and
 - g) transferring force to the load transfer mechanism (299).

Patentansprüche**1.** Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300), umfassend:

1) einen Reihen-Elasto-Aktuator, umfassend:

1.1) einen Reihen-Elasto-Momenten-Sensor (302), umfassend:

1.1.1) eine Torsionsfeder (411), welche eine Eingabeseite und eine Ausgabeseite aufweist;

1.1.2) wenigstens einen Feder-Positionssensor (312, 313), welcher dazu eingerichtet ist, eine Auslenkung der Torsionsfeder (411) zu messen;

1.2) einen über ein Getriebe rotierenden Motor mit variabler Geschwindigkeit, umfassend einen Motor (304), welcher an einer Getriebe-Reduktionseinheit (303) angebracht ist;

1.3) eine programmierbare Motor-Steuer-einheit (305);

2) einen Last-Transfer-Mechanismus (299), umfassend eine Umlenkrolle oder eine Spule;

wobei der wenigstens eine Feder-Positionssensor (312, 313) in Kommunikation mit der programmierbaren Motor-Steuer-einheit (305) ist; und wobei der über ein Getriebe rotierende Motor mit variabler Geschwindigkeit mit der Eingabeseite der Torsionsfeder (411) verbunden ist und der Last-Transfer-Mechanismus (299) mit der Ausgabeseite der Torsionsfeder (411) verbunden ist.

2. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, wobei

a) der Reihen-Elasto-Momenten-Sensor (302) in Kommunikation ist mit

(i) einem Schaft des über ein Getriebe rotierenden Motors mit variabler Geschwindigkeit;

(ii) wenigstens einem planaren Torsion-Feder-Positionssensor (312, 313) in Kommunikation mit einem Mikroprozessor;

b) der Mikroprozessor in Kommunikation mit einem intelligenten Servo-Antrieb ist;

c) der Servo-Antrieb in Kommunikation mit dem über ein Getriebe rotierenden Motor mit variabler Geschwindigkeit ist;

d) der Schaft des über ein Getriebe rotierenden Motors mit variabler Geschwindigkeit in einer

Eingabeseite (420) des Reihen-Elasto-Momenten-Sensors (302) angebracht ist; und e) der Mikroprozessor eine Rotation des Schafts des über ein Getriebe rotierenden Motors mit variabler Geschwindigkeit steuert.

3. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend einen Mikroprozessor, welcher die Geschwindigkeit der Rotation des Schafts des über ein Getriebe rotierenden Motors mit variabler Geschwindigkeit steuert.

4. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 2, wobei der Mikroprozessor auf eine Kraft reagiert, welche auf den Last-Transfer-Mechanismus (299) ausgeübt wird.

5. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend einen Mikroprozessor, welcher die Kraft steuert, welche durch die Rotation des Schafts des über ein Getriebe rotierenden Motors mit variabler Geschwindigkeit erzeugt wird.

6. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 4, wobei der Mikroprozessor, welcher die Kraft der Rotation des Schafts des über ein Getriebe rotierenden Motors mit variabler Geschwindigkeit steuert, auf die Geschwindigkeit reagiert, welche auf den Last-Transfer-Mechanismus (299) ausgeübt wird.

7. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, wobei Signale von den Momenten-Sensoren (312, 313) eine Eingabe an einen Mikroprozessor umfassen, um die Wirkung des Schafts des über ein Getriebe rotierenden Motors mit variabler Geschwindigkeit zu steuern.

8. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine Getriebe-Reduktionseinheit (303) für den über ein Getriebe rotierenden Motor mit variabler Geschwindigkeit.

9. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine Planetengetriebe-Reduktionseinheit (303) für den rotierenden Motor mit variabler Geschwindigkeit.

10. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine Getriebe-Reduktionseinheit vom Stirnradtyp (304) für den rotierenden Motor mit variabler Geschwindigkeit.

11. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine Getriebe-Reduktionseinheit vom Helix-Typ (303) für den rotierenden Motor mit variabler Geschwindigkeit. 5
12. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine zyklonoide Getriebe-Reduktionseinheit (303) für den rotierenden Motor mit variabler Geschwindigkeit. 10
13. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine Getriebe-Reduktionseinheit eines harmonischen Antriebs (303) für den rotierenden Motor mit variabler Geschwindigkeit. 15
14. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend einen Reihen-Elasto-Momenten-Sensor (302). 20
15. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine planare Torsionsfeder (411). 25
16. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, wobei der Last-Transfer-Mechanismus (299) einen Riemen mit einem anbringbaren ersten Ende und einem zweiten Ende umfasst, welches an einer Spule angebracht ist. 30
17. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine Schnittstellen-Vorrichtung. 35
18. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 17, wobei die Schnittstellen-Vorrichtung in Kommunikation mit einem Mikroprozessor ist. 40
19. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, wobei die Vorrichtung isokinetische Übungen durchführt. 45
20. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, wobei die Vorrichtung Übungen in einem isotonischen Modus durchführt. 50
21. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, wobei die Vorrichtung Übungen in einem isometrischen Modus durchführt. 55
22. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine Motor-Steuereinheit, welche eine eingebettete Intelligenz enthält, um die Menge einer Kraft zu ändern, welche auf den Last-Transfer-Mechanismus (299) ausgeübt wird, auf Grundlage einer Position des Last-Transfer-Mechanismus (299).
23. Motorisierte Momenten-steuerbare Trainingsgerät-Vorrichtung (300) nach Anspruch 1, ferner umfassend eine programmierbare Motor-Steuereinheit (305), welche eine eingebettete Intelligenz enthält, um alternierend die Geschwindigkeit oder die Kraft zu steuern, welche durch den Motor (304) erzeugt wird, in Reaktion auf variable Eingaben einer Kraft oder einer Geschwindigkeit von dem Last-Transfer-Mechanismus (299).
24. Verfahren eines Herstellens von variablen Lasten in Reaktion auf eine Kraft oder eine Geschwindigkeit einer Bewegung an einer motorisierten Momenten-steuerbaren Trainingsgerät-Vorrichtung (300), umfassend die Schritte:
- 1) Bereitstellen eines Reihen-Elasto-Aktuators, umfassend:
- 1.1) einen Reihen-Elasto-Momenten-Sensor (302), umfassend:
- 1.1.1) eine Torsionsfeder (411), welche eine Eingabeseite und eine Ausgabeseite aufweist;
- 1.1.2) wenigstens einen Feder-Positionssensor (312, 313), welcher dazu eingerichtet ist, eine Auslenkung der Torsionsfeder (411) zu messen;
- 1.2) einen über ein Getriebe rotierenden Motor mit variabler Geschwindigkeit, umfassend einen Motor (304), welcher an einer Getriebe-Reduktionseinheit (303) angebracht ist;
- 1.3) eine programmierbare Motor-Steuereinheit (305);
- 2) Bereitstellen eines Last-Transfer-Mechanismus (299), umfassend eine Umlenkrolle oder eine Spule;
- wobei der wenigstens eine Feder-Positionssensor (312, 313) in Kommunikation mit der programmierbaren Motor-Steuereinheit (305) ist; und wobei der über ein Getriebe rotierende Motor mit variabler Geschwindigkeit mit der Eingabeseite der Torsionsfeder (411) verbunden ist und der Last-Transfer-Mechanismus (299) mit der Ausgabeseite der Torsionsfeder (411) verbunden ist.
25. Verfahren nach Anspruch 24, umfassend die Schritte:

te:

- a) Eingeben einer Last in den Last-Transfer-Mechanismus (299);
- b) Transferieren der Last auf den Reihen-Elasto-Momenten-Sensor (302), welcher eine Torsionsfeder (411) umfasst;
- c) Kommunizieren eines Feder-Auslenkung-Momenten-Signals an die programmierbare Motor-Steuereinheit (305);
- d) Anweisen der Bewegung des Motors (304) durch die programmierbare Motor-Steuereinheit (305);
- e) Einstellen der Bewegung des Motors (304) durch die Getriebe-Reduktionseinheit (303);
- f) Transferieren einer Kraft an den Reihen-Elasto-Momenten-Sensor (302); und
- g) Transferieren einer Kraft an den Last-Transfer-Mechanismus (299).

Revendications

1. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) comprenant :

- 1) un actionneur élastique en série, comprenant :

- 1.1) un capteur de couple élastique en série (302), comprenant :

- 1.1.1) un ressort de torsion (411), ayant un côté entrée et un côté sortie ;
- 1.1.2) au moins un capteur de position de ressort (312, 313), configuré pour mesurer une flexion du ressort de torsion (411) ;

- 1.2) un moteur à vitesse variable tournant à engrenages, comprenant un moteur (304) attaché à un réducteur à engrenages (303) ;
- 1.3) un dispositif de commande de moteur programmable (305) ;

- 2) un mécanisme de transfert de charge (299), comprenant une poulie ou bobine ;

dans lequel l'au moins un capteur de position de ressort (312, 313) est en communication avec le dispositif de commande de moteur programmable (305) ; et

dans lequel le moteur à vitesse variable tournant à engrenages est relié au côté entrée du ressort de torsion (411), et le mécanisme de transfert de charge (299) est relié au côté sortie du ressort de torsion (411).

2. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1, dans lequel

- a) le capteur de couple élastique en série (302) est en communication avec

- (i) un arbre du moteur à vitesse variable tournant à engrenages ;
- (ii) au moins un capteur de position de ressort de torsion plan (312, 313) en communication avec un microprocesseur ;

- b) le microprocesseur étant en communication avec une servocommande intelligente ;
- c) la servocommande étant en communication avec le moteur à vitesse variable tournant à engrenages ;
- d) l'arbre du moteur à vitesse variable tournant à engrenages étant attaché dans un côté entrée (420) du capteur de couple élastique en série (302) ; et
- e) le microprocesseur commandant une rotation de l'arbre du moteur à vitesse variable tournant à engrenages.

3. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un microprocesseur commandant la vitesse de la rotation de l'arbre du moteur à vitesse variable tournant à engrenages.

4. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 2 dans lequel le microprocesseur répond à une force appliquée sur le mécanisme de transfert de charge (299).

5. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un microprocesseur commandant la force créée par la rotation de l'arbre du moteur à vitesse variable tournant à engrenages.

6. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 4 dans lequel le microprocesseur commandant la force de la rotation de l'arbre du moteur à vitesse variable tournant à engrenages répond à la vitesse appliquée sur le mécanisme de transfert de charge (299).

7. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1, dans lequel des signaux provenant des capteurs de couple (312, 313) comprennent une entrée dans un microprocesseur pour commander l'action de l'arbre du moteur à vitesse variable tournant à

- engrenages.
8. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un réducteur à engrenages (303) pour le moteur à vitesse variable tournant à engrenages. 5
 9. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1, comprenant en outre un réducteur à engrenages planétaires (303) pour le moteur à vitesse variable tournant. 10
 10. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1, comprenant en outre un réducteur à engrenages de type droit (304) pour le moteur à vitesse variable tournant. 15
 11. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un réducteur à engrenages de type hélicoïdal (303) pour le moteur à vitesse variable tournant. 20
 12. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un réducteur à engrenages cycloïdaux (303) pour le moteur à vitesse variable tournant. 25
 13. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un réducteur à engrenages de transmission harmonique (303) pour le moteur à vitesse variable tournant. 30
 14. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un capteur de couple élastique en série (302). 35
 15. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un ressort de torsion plan (411). 40
 16. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 dans lequel le mécanisme de transfert de charge (299) comprend une courroie avec une première extrémité attachable et une seconde extrémité attachée à une bobine. 45
 17. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un dispositif d'interface. 50
 18. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 17, dans lequel le dispositif d'interface est en communication avec un microprocesseur. 55
 19. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 dans lequel l'appareil effectue des exercices isocinétiques.
 20. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 dans lequel l'appareil effectue des exercices dans un mode isotonique.
 21. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 dans lequel l'appareil effectue des exercices dans un mode isométrique.
 22. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un dispositif de commande de moteur contenant une intelligence embarquée pour changer la quantité de force appliquée sur le mécanisme de transfert de charge (299) sur la base d'une position du mécanisme de transfert de charge (299).
 23. Appareil de machine d'exercice pouvant être commandé en couple motorisé (300) selon la revendication 1 comprenant en outre un dispositif de commande de moteur programmable (305) contenant une intelligence embarquée pour commander en alternance la vitesse ou force générée par le moteur (304) en réponse à des entrées variables de force ou de vitesse à partir du mécanisme de transfert de charge (299).
 24. Procédé pour produire des charges variables en réponse à une force ou une vitesse de mouvement sur un appareil de machine d'exercice pouvant être commandé en couple motorisé (300), comprenant des étapes consistant à :
 - 1) fournir un actionneur élastique en série, comprenant :
 - 1.1) un capteur de couple élastique en série (302), comprenant :
 - 1.1.1) un ressort de torsion (411), ayant un côté entrée et un côté sortie ;
 - 1.1.2) au moins un capteur de position de ressort (312, 313), adapté pour mesurer une flexion du ressort de torsion (411) ;

- 1.2) un moteur à vitesse variable tournant à engrenages, comprenant un moteur (304) attaché à un réducteur à engrenages (303) ;
 1.3) un dispositif de commande de moteur programmable (305) ; 5

2) fournir un mécanisme de transfert de charge (299), comprenant une poulie ou bobine ;

dans lequel l'au moins un capteur de position de ressort (312, 313) est en communication avec le dispositif de commande de moteur programmable (305) ; et 10

dans lequel le moteur à vitesse variable tournant à engrenages est relié au côté entrée du ressort de torsion (411), et le mécanisme de transfert de charge (299) est relié au côté sortie du ressort de torsion (411). 15

25. Procédé selon la revendication 24, comprenant les étapes consistant à : 20

- a) entrer une charge dans le mécanisme de transfert de charge (299) ;
 b) transférer la charge au capteur de couple élastique en série (302) contenant un ressort de torsion (411) ; 25
 c) communiquer un signal de couple de flexion de ressort au dispositif de commande de moteur programmable (305) ; 30
 d) ordonner le mouvement du moteur (304) par le dispositif de commande de moteur programmable (305) ;
 e) ajuster le mouvement du moteur (304) par l'intermédiaire du réducteur à engrenages (303) ; 35
 f) transférer une force au capteur de couple élastique en série (302) ; et
 g) transférer une force au mécanisme de transfert de charge (299). 40

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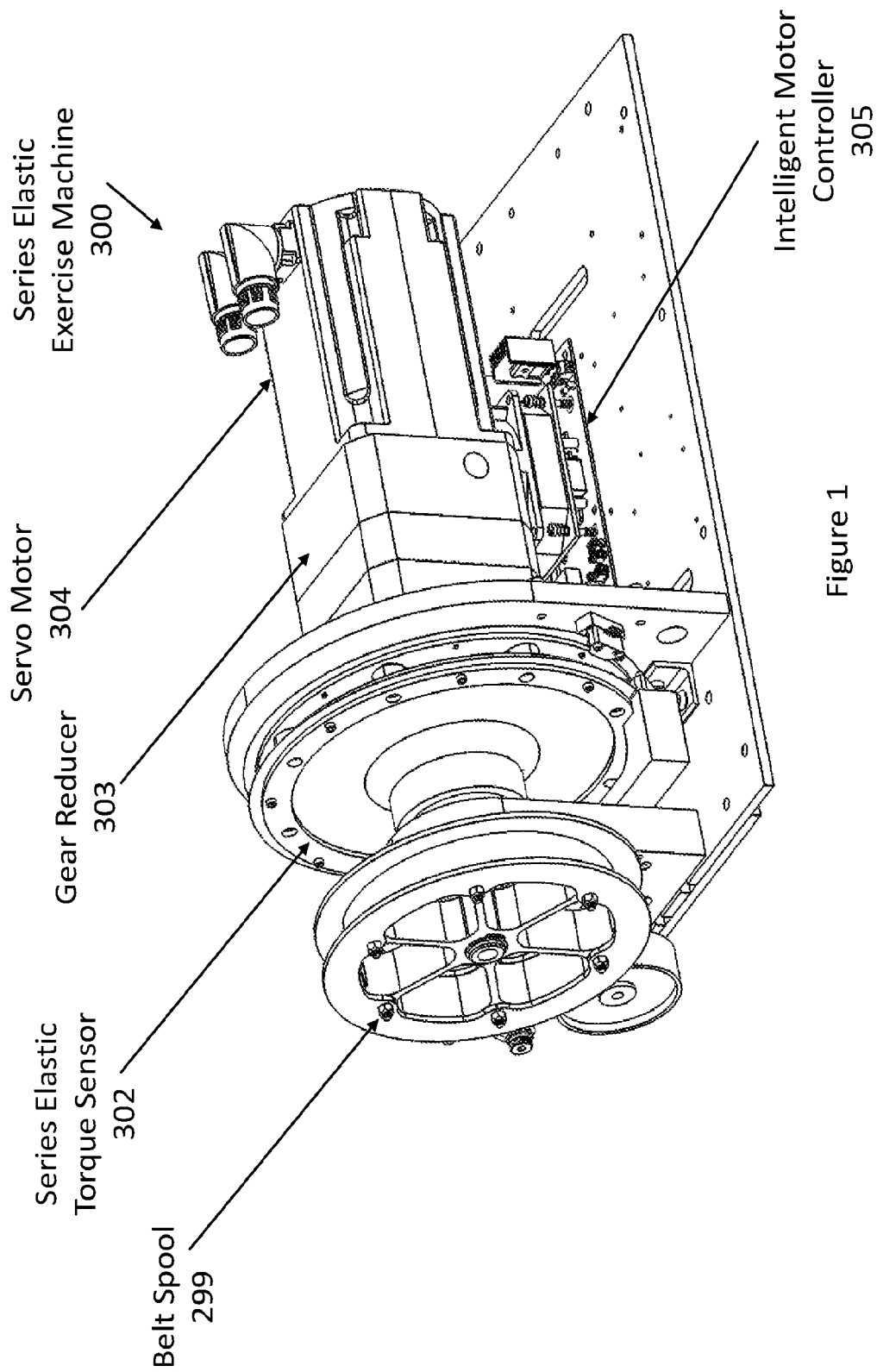


Figure 1

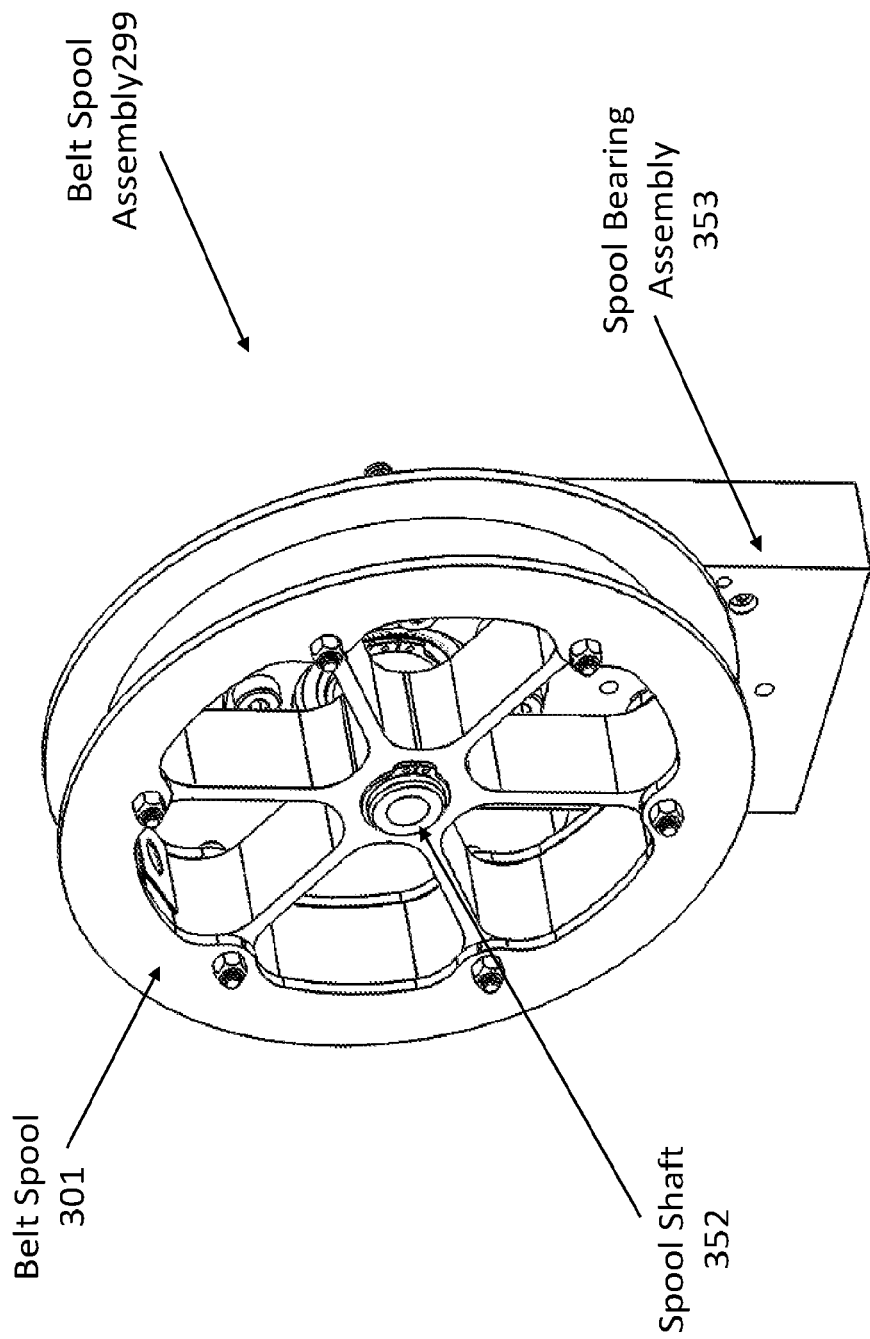


Figure 2

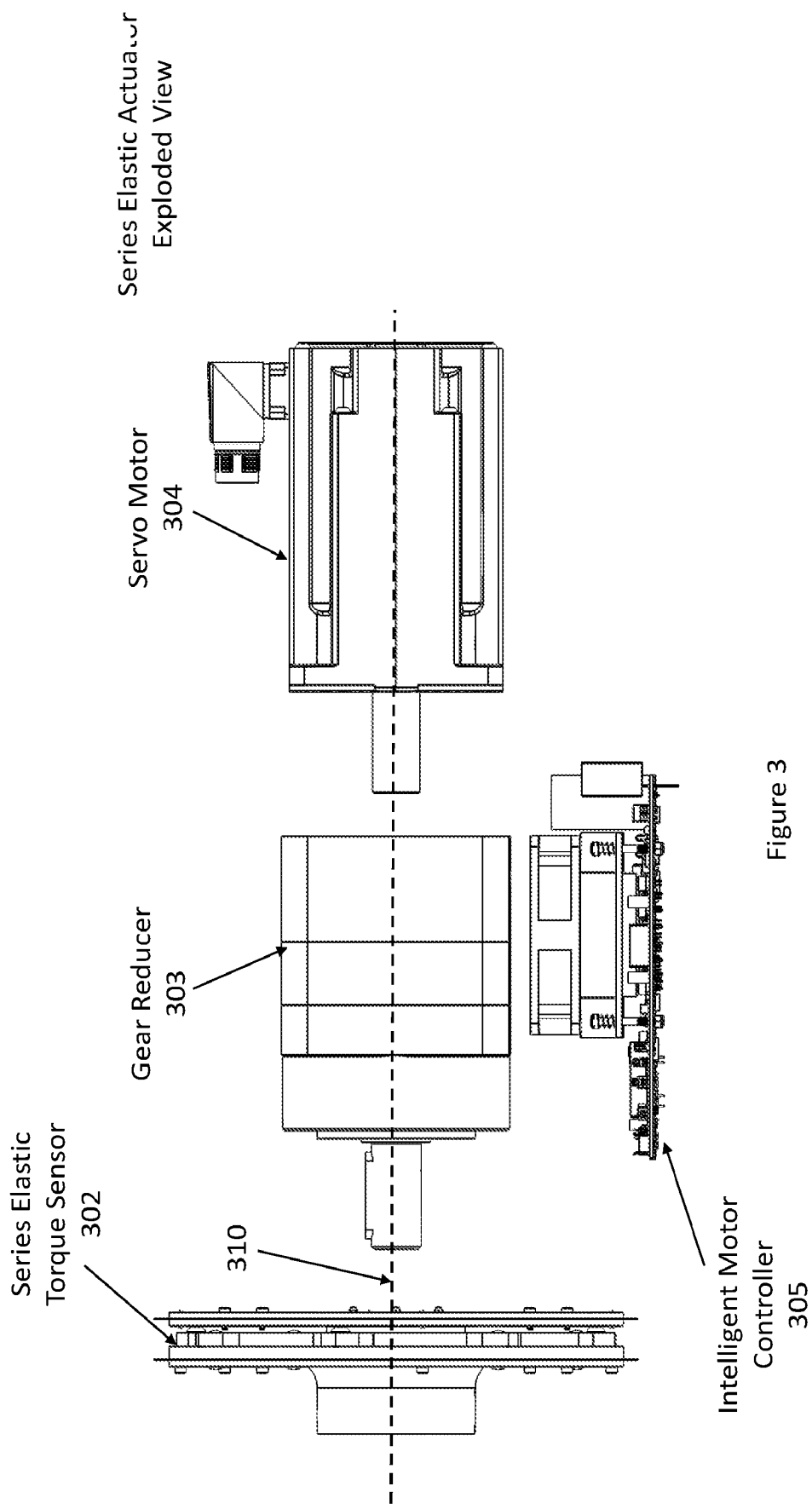


Figure 3

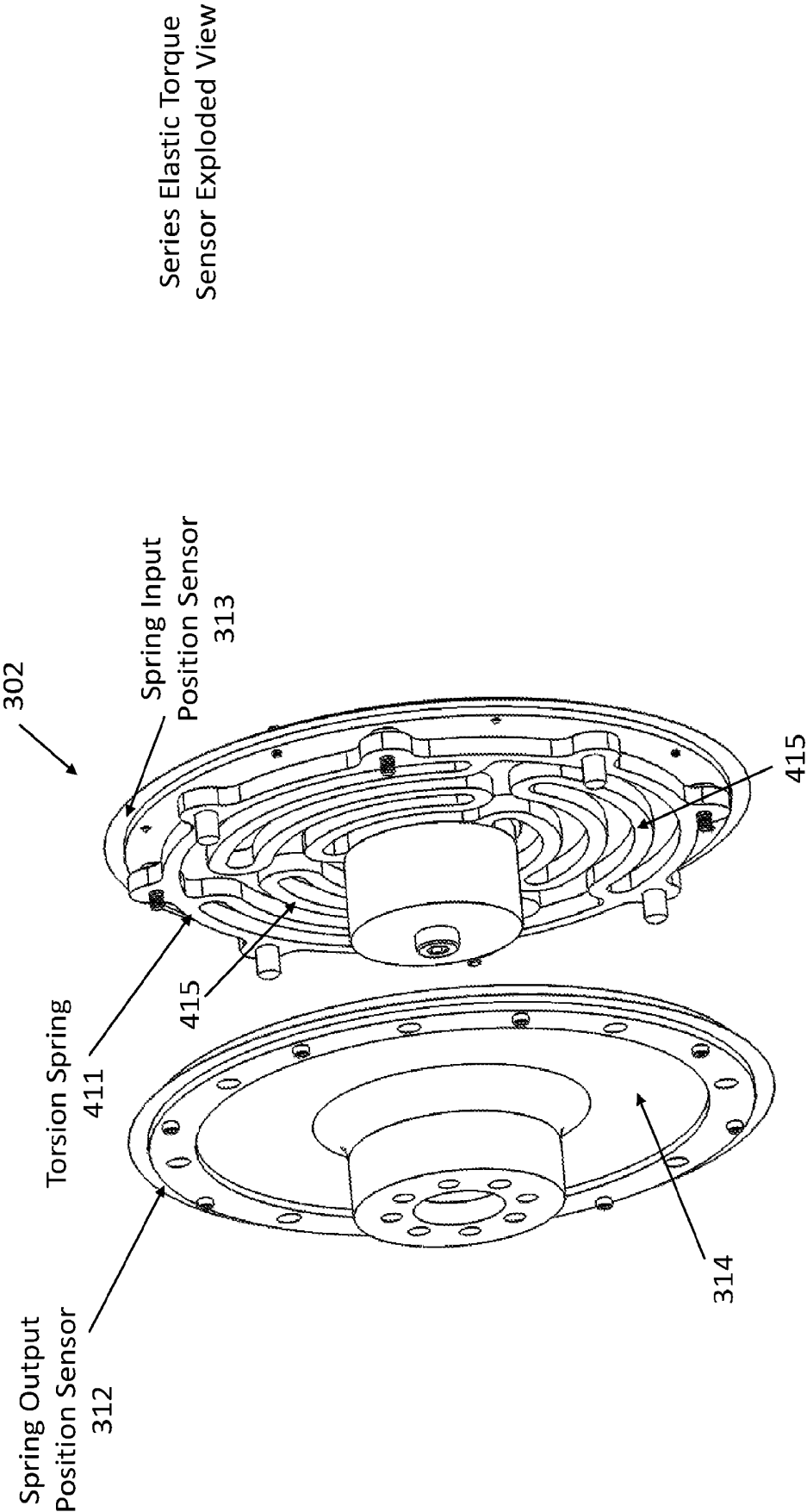


Figure 4

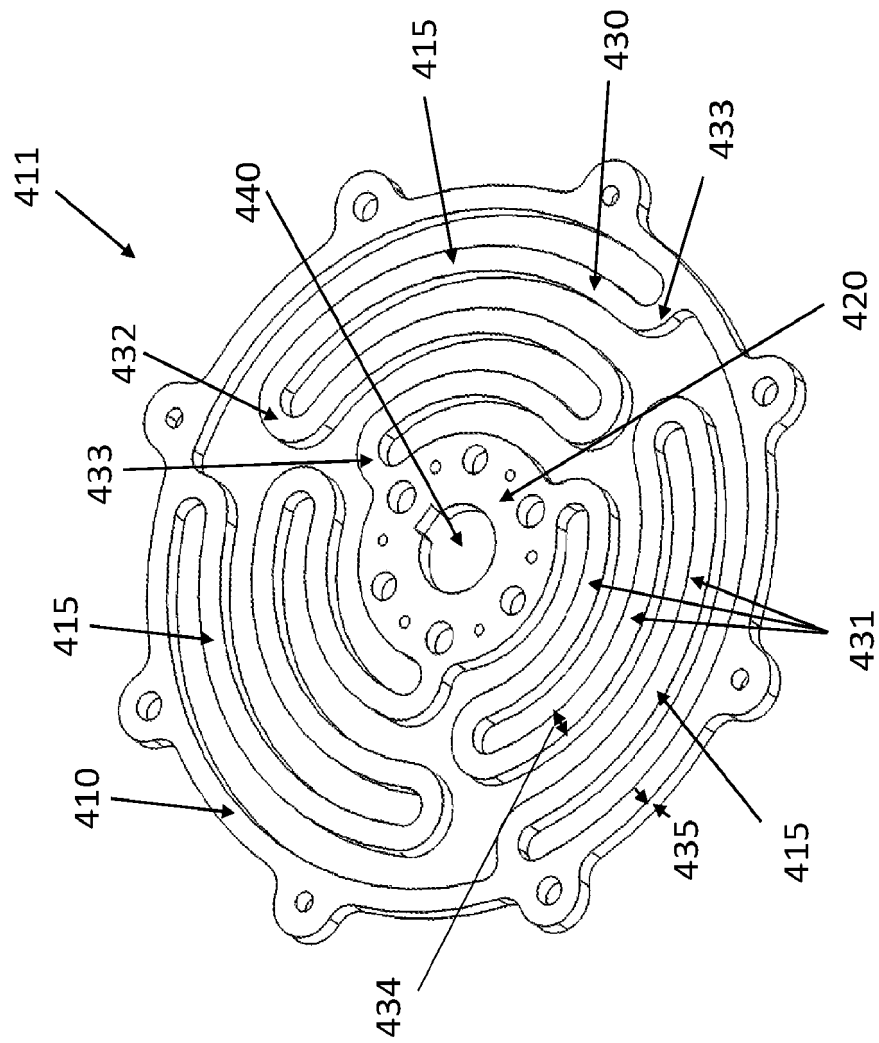


Figure 5

TIME 1

1. Spring output position sensor monitors torsion spring output side
2. Does sensor detect movement? Y/N
Yes
3. Intelligent motor controller calculates amount of movement (degree of rotation of deflection)
4. Motor controller calculates force based on the amount of movement and spring constant
5. Has spring input position sensor detected movement of torsion spring input side? Y/N
6. If yes, motor controller calculates force based on amount of movement and spring constant
7. Motor controller reconciles calculated force on output side with calculated force on input side.

TIME 2

8. Has spring output position sensor detected additional movement of torsion spring output side?
Y/N

No

9. Motor controller recalculates force based on static degree of rotation of deflection and spring constant.

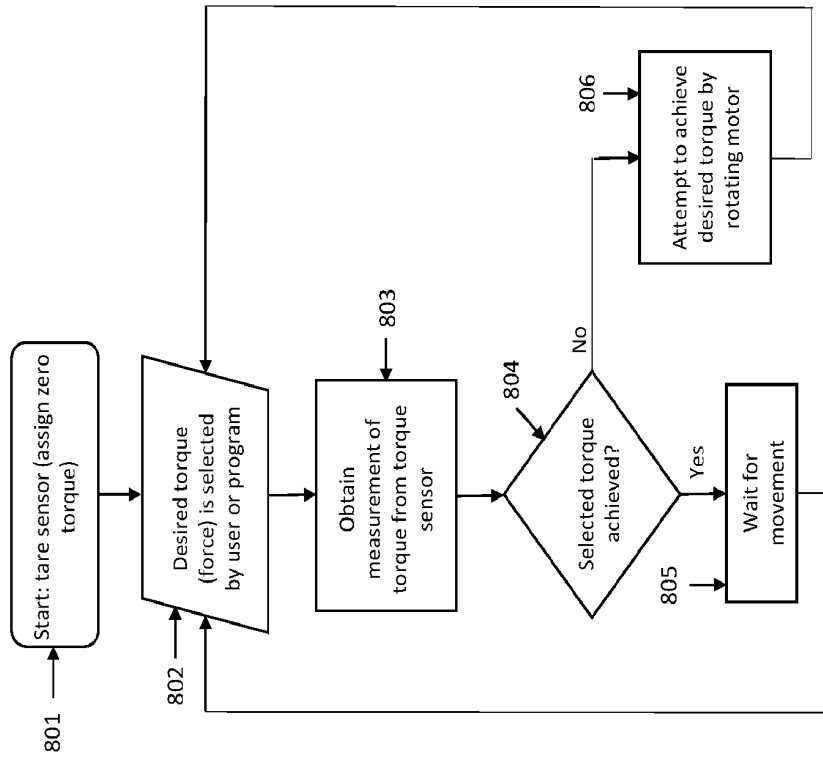
If yes, repeat steps 3 through 7

Figure 6

1. Monitor spring input position sensor (Assume no load on input side)
2. Does torsion spring input side move? Y/N
Yes
3. Motor controller computes amount of movement (degrees of rotation of deflection)
4. Motor controller computes force on torsion spring output side using calculated amount of movement of input side and spring constant
5. Does torsion spring output side move? Y/N
Yes
6. Motor controller computes amount of movement
7. Motor controller reconciles calculated force from torsion spring input side with calculated force from torsion spring output movement
8. Motor controller computes off set (counterbalance) force for torsion spring input side

Figure 7

Torque control is one application of the sensor, and the exercise devise is a use Of that application. Torque control using the torque sensor looks like this:



With torque control, the specific construction and operation of the torque sensor isn't important – the sensor is treated as a black box. For the exercise device, the construction of the torque sensor is important because of cost and accuracy so that's the advantage of our particular torque sensor.

Figure 8

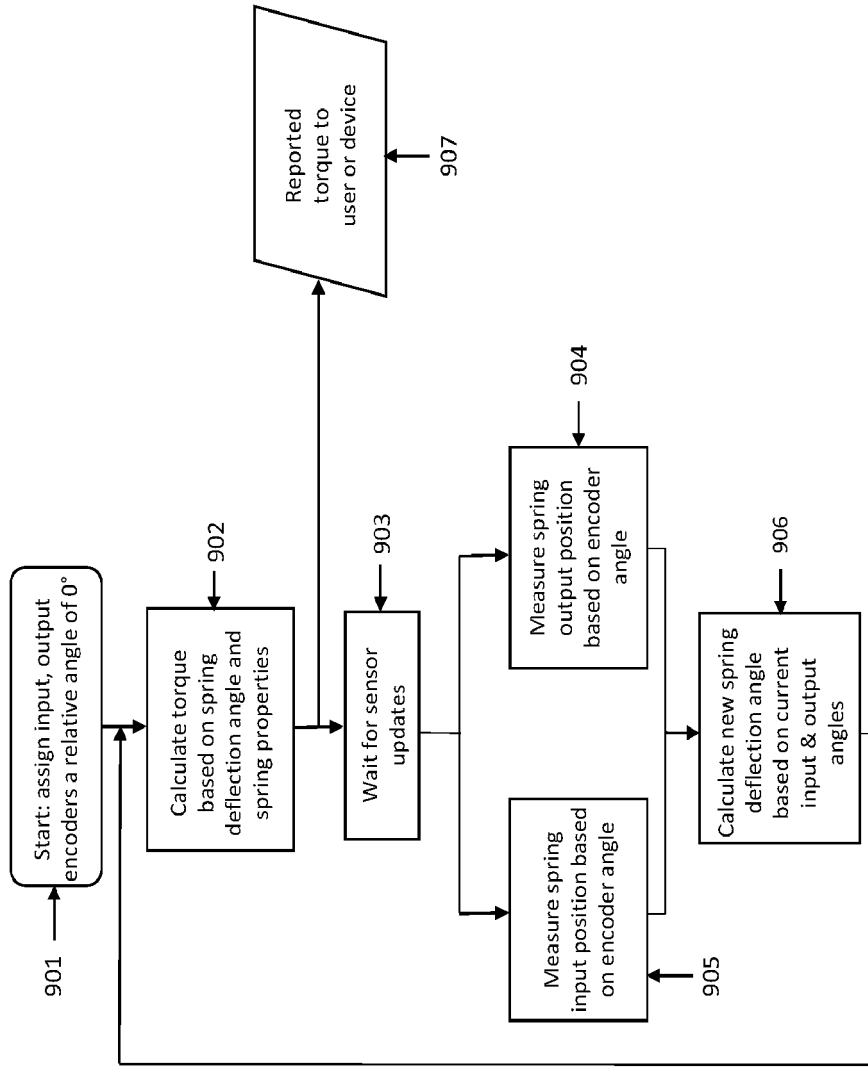


Figure 9

Encoders can rotate 360° and do not report an absolute position, so the starting position is assumed to be 0

Given an input and output angle, the deflection of the spring is known; that information along with known spring properties can be used to calculate the torque or force applied to the spring

New encoder data is read on a periodic basis

Encoders read spring input and output position from the same fixed reference point so that relative movement can be obtained.

REFERENCES CITED IN THE DESCRIPTION

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