(19) Octrooicentrum Nederland

(11) **2021908**

(12) B1 **OCTROOI**

(21) Aanvraagnummer: **2021908**

(22) Aanvraag ingediend: **31 oktober 2018**

(51) Int. Cl.:
B01L 3/10 (2019.01)

(30) Voorrang:

(41) Aanvraag ingeschreven:
14 mei 2020

(43) Aanvraag gepubliceerd:
-

(47) Octrooi verleend:
14 mei 2020

(45) Octrooischrift uitgegeven:
15 mei 2020

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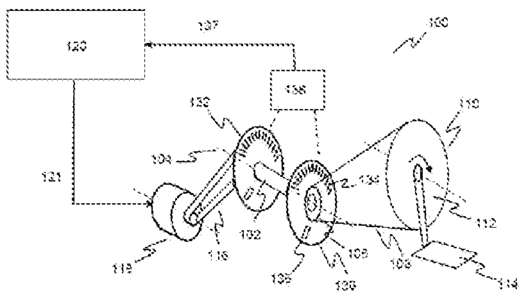
(54) **A torque sensing system**

(57) A torque sensing system is described comprising: a rotatable shaft having a first part and a second part, the shaft comprising a deformable spring structure between the first and second part; a first readout structure connected to the first part comprising a plurality of first position indicators and a second readout structure connected to the second part comprising a plurality of second position indicators; an encoder system configured to measure a first rotatory position of the first part of the shaft based on the plurality of first position indicators and a first reference indicator and a second rotary position based on the plurality of second position indicators and a second reference indicator; and, wherein in response to a first torque applied to the first part and a second torque applied to the second part, the second torque having direction opposite to the first torque, the spring structure providing a relative shift in the rotary position between the first and second part, the first and second absolute rotary position measured by the encoder system defining an angle of twist of the shaft.



NL B1 2021908

A torque sensing system

Field of the invention

The invention relates to a torque sensing system, and, in particular, though not exclusively, methods and devices for determining a torque for a force feedback system, for example a force feedback system for an exercise apparatus, a computer-controlled exercise apparatus comprising such torque sensing system, a torsion spring structure for such torque sensing system and a computer program product for executing such methods.

Background of the invention

Force feedback systems are used to create forces in a mechanical system to simulate a real-life situation. For example, in modern exercise equipment the reality is mimicked using a force-feedback system applying some form of counter force to the motion of the athlete based on his current state, which is determined based on sensor information. Most commonly, the current state of the athlete is measured by sensors in terms of position, speed and force. Based on the sensor information a resistive force that the apparatus should provide is calculated by a computer and used to control an apparatus that is capable of generating a variable resistive force using mechanical, electrical and/or magnetic means. Typically, both during measurements and the calculation of the resistive force a considerable amount of averaging is applied to limit the speed at which the resistive forces change since large fluctuations in the resistive forces are difficult (expensive) to apply and can pose significant threat to the athlete.

US7,833,135 describes an example of an exercise apparatus, a spinning bike, including a computer-controlled force generating device which generates a resistive (braking) force based on a measured velocity (using an encoder coupled to the crank) and a measured force (e.g. using a force sensor). Based on a simple force equation (a kinetic model) the spinning bike can be modelled, wherein a computer may determine a computed velocity and compare the computed velocity with a measured velocity and control the generation of the resistive force on the basis of the difference between the calculated and the measured velocity. This way, a resistive force can be applied to the wheel of the bike to mimic the force experienced by an athlete on a real bike. The scheme described in US7,833,135 however does not provide an athlete with a true outdoor biking experience. For such experience, the resistive force needs to be determined real-time based accurately measured sensor information. The averaging of the measurements and the proposed sensors are not suitable for accurately determining sensor data at a very high rate. The proposed force sensor is mounted on the crank and relies on changes in the intensity of a reflected optical analogous signal, which is very sensitive to noise. Further, the sample frequency of the sensor is limited do the fact that the optical signal is accessible via holes of in the crank set.

In the field of bicycles and electrical bicycles it is known to monitor the performance of a rider by measuring the torque and the power applied by a user to the axis of the crank. For example, WO2014/132021 describes a torque sensor for a bicycle which is configured to measure small deformations of the crank shaft due to the applied torque using two encoder wheels connected to both ends of the shaft, wherein the encoder wheels comprise 32 alternating teeth and gaps along the periphery of the wheel. The relative angular displacement (the angle of twist) at each time instance between the two encoder wheels provides a measure of the applied torque as a function of time, wherein the maximum angle of twist that can be measured by such sensor is 360 degrees divided by the number of position indicators.

When using a torque sensor in a force feedback system for an exercise apparatus high frequency feedback (>100 Hz) is needed in order to accurately generate reaction forces in the exercise equipment in which rotational speeds are of the order of 10 rpm. In such case, the above-described torque sensor only provides a sampling frequency of 5 Hz. If high frequency feedback is needed (> 100Hz), either the rotation speed needs to be high (e.g. 190 rpm 32 indicators renders a sampling frequency of around 100 Hz), or many position indicators are needed (e.g. 6 rpm and 1000 readout element still only yields a sampling frequency of 100 Hz). It is however not economically feasible to have high rotational speeds in an exercise apparatus wherein rotational speeds are typically in the order of magnitude of 10 rpm. Moreover, increasing the number of position indicators up to 1000 or more, the maximum measurable torsion angle would only be around 0.36 degrees (360/1000) thus providing a very low signal to noise ratio, or in other words very unreliable measurements. More generally, torque sensors known from industry typically use a straight torsion bar which allows for very small deformations before plastic, and therefore unwanted irreversible, deformation of the bar occurs. In order to achieve more accurate measurements, larger deformations are needed, which is typically achieved using a longer torsion bar. However, in many exercise apparatus designs the use of long torsion bars is not feasible.

Hence, from the above it follows that there is a need in the art for an improved torque sensor and an improved computer-controlled force feedback system using such torque sensor. In particular, there is a need in the art for torque sensor that is capable of providing a high signal to noise ratio and high frequency feedback at low rotation speeds which can be used in a force feedback system of an exercise apparatus that can provide a real-life exercise experience.

Summary of the invention

It is an objective of the invention to reduce or eliminate at least one of the drawbacks known in the prior art.

In an aspect, the invention relates to a torque sensing system comprising:
a rotatable shaft having a first part and a second part, the shaft comprising a spring structure between the first and second part; a first readout structure connected to the first part comprising first position indicators and a second readout structure connected to the second part comprising a second position indicators; an encoder system configured to measure a first absolute rotary position of the first part of the shaft based on the first position indicators and a second absolute rotary position based on the second position indicators; wherein in response to an external force to the first and/or second part, the difference between a first and second absolute rotary position measured by the encoding system determining an angle of twist. Thus, absolute rotary positions of two parts of a rotatable shaft are measured based on position indicators on a readout structure connected to the shaft, so that an angle of twist can be determined which correlates with an external force (a torque) that is applied

to the shaft at each time instance. Because the encoder system is configured to measure an absolute rotary position of both readout structures, the relative shift between the position indicators may be larger than the rotational angle between two subsequent position indicators of the first readout structure or the second readout structure.

Here, the term position indicator may include any means that can be detected or imaged and used to determine an absolute rotary position of the shaft. A position indicator may include one or more optically, magnetically, mechanically and/or magnetically elements which can be detected by a suitable detector or camera.

In an embodiment, the spring structure may be configured to provide a maximum angle of twist which is larger than the rotary angle between two subsequent position indicators of the first and second readout structure. The external force will induce a reversible torsional deformation in the spring structure of the shaft, wherein the spring structure is configured such that the relative rotational shift between the position indicators of the readout structures (e.g. the difference between the first and second absolute rotary position) of the readout structures connected to the first and second part of the shaft can be larger than the rotational angel between two position indicators. This way, a large signal to noise ratio can be obtained.

In an embodiment, the spring structure may be configured to provide an angle of twist between -20 and 20 degrees. In another embodiment, the angel of twist may be between -10 and 10 degrees.

In an embodiment, the spring structure may comprise a torsion spring, preferably a spiral torsion spring. Such as spring structure may be used to address the problem of realizing a shaft structure that exhibits large torsion angles. Such spiral torsion spring structure allows a compact spring structure which provides a substantial angle of twist in response to the externally applied force.

In an embodiment, first readout structure may comprise at least a first reference indicator, wherein the encoder system is further configured to determine an absolute rotary position of the first reference indicator and to determine an absolute position of at least one of the plurality of position indicators based on the absolute position of the first reference indicator. In this embodiment, the reference position of a reference indicator is determined. As the position of the reference indicator relative to the position indicators is accurately known, the absolute position of each position indicators can be determined. Here, the term reference indicator may include any means that can be detected or imaged and used to determine an absolute reference (rotary) position of the shaft. Similar to a position indicator, a reference indicator may include one or more optically, mechanically, capacitively and/or magnetically elements which can be detected by a suitable detector or camera.

In an embodiment, each of the first position indicators may be associated with unique code (e.g. one or more markers, numbers, symbols, coded slots or combinations thereof). In an embodiment, the encoder system may be further configured to determine an absolute rotary position for each position indicated based on the associated unique code. In an embodiment, the encoder system may include a memory comprising a lookup table comprising the unique codes and rotary position of the position indicators. In another embodiment, the encoder system may include module for executing an algorithm that provides a functional relation between the unique codes and rotary positions of the position indicators. In this embodiment, each position indicator is associated with a unique code which provides a direct measure of the absolute rotary position of the position indicator.

In another embodiment, the first readout structure may include a disc connected to the first part of the shaft wherein the first position indicators are positioned along the periphery of the disc; and/or, wherein the second readout structure includes a second disc connected to the second part of the shaft, wherein the second position indicators are positioned along the periphery of the second disc.

In an embodiment, the encoder system may include one or more detectors for detecting the position indicators. In another embodiment, the encoder system may include one or more imaging sensors for imaging the position indicators. Further, a processor in the encoder system may be configured to analyse images and determine positions of the position indicators based on known image analysis techniques.

In a further aspect, the invention may relate to a feedback system for an exercise apparatus comprising a torque sensing system according to any of the embodiments described above.

In an embodiment, the feedback system may include a force generating device connected to the second part of the rotatable shaft and a computer comprising a processor configured to: in response to a first torque applied to the first part of the rotatable shaft; receiving from the torque sensing system first absolute position information of the first part of the rotatable shaft and second absolute position information of the second part of the rotatable shaft; using the first and second absolute position information to compute an angle of twist between the first part and second part of the shaft; and, computing a control signal for the force generating device, the control signal instructing the force generating device to exert a second torque to the second end of the shaft, the second torque being opposite to the first torque.

In an aspect, the invention may relate to a computer-controlled exercise apparatus comprising: a frame; a shaft rotatable mounted to the frame; at least one force receiving structure rotatably connected to a first part of the rotatable shaft; and, a force generating device connected to the second part of the rotational shaft; an encoder system configured to measure first absolute position information of the first part of the rotatable shaft and to measure second absolute position information of the second part of the rotatable shaft, the first and second position information being generated by the encoder system in response to a user of the exercise apparatus applying a force to the force receiving structure, the force exerting a first torque to the first part of the rotatable shaft; and, a force feedback system including a computer-controlled force generating device rotatable connected to the second part of the shaft and a processor of a computer configured to determine an angle of twist between the first and second part of the shaft on the basis of the first and second absolute position information and to control the force generating device to exert a second torque to the second part of the shaft, based on the first and second position information, the second torque being opposite to the first torque.

In an embodiment, the computer-controlled exercise may further comprise:

a first readout structure connected to the first part comprising first position indicators and a second readout structure connected to the second part comprising a second position indicators; wherein the encoder system is configured to measure first absolute position information based on the first position indicators and the second absolute position information based on the second position indicators.

In an embodiment, the exercise apparatus may be a stationary exercise bicycle. In an embodiment, the rotatable shaft may be the rear axis of the exercise bicycle or being rotatable connected to the rear axis of the exercise bicycle. In another embodiment, the first part of the rotatable shaft may be connected to a gear, wherein a transmission system, preferably including a chain or a band, may connect the gear to a crank

In an embodiment, the rotatable shaft may include a torsion spring structure in the shape of a spiral rotary spring, wherein the spiral rotary spring being may be contained in a (circular) enclosure, the spiral rotary spring including an outer end connected to the outer enclosure, the outer enclosure being connected to the first part of the shaft and the spiral rotary spring including an inner end connected to the second part of the shaft.

In an embodiment, the processor of the force feedback system may use an algorithm based on a kinematic model of the exercise apparatus to determine a value of the second torque using the angle of twist as input information.

In an aspect, the invention relates to a torque sensing system comprising: a rotatable shaft having a first part and a second part, the shaft comprising a deformable spring structure between the first and second part; a first readout structure connected to the first part comprising a plurality of first position indicators and a second readout structure connected to the second part comprising a plurality of second position indicators; an encoder system configured to measure a first rotatory position of the first part of the shaft based on the plurality of first position indicators and a first reference indicator and a second rotary position based on the plurality of second position indicators and a second reference indicator; and, wherein in response to a first torque applied to the first part and a second torque applied to the second part, the second torque having direction opposite to the first torque, the spring structure providing a relative shift in the rotary position between the first and second part, the first and second absolute rotary position measured by the encoder system defining an angle of twist of the shaft.

Since the angle of twist is computed based on the absolute rotational position the first and second part of the shaft, the measured angle is independent of the spatial angle between both indicators. This way, it is possible to measure angle of twists that substantially larger than the angel between two subsequent position indicators.

In an embodiment, the spring structure is configured such that the maximum angle of twist provided by the spring structure in response to the external force is larger than the rotary angle defined as the angle between two subsequent position indicators of the first and second readout structure.

In an embodiment, the plurality of first position indicators and the first reference indicator may form a first readout structure, preferably a readout structure in the form of a disc wherein the plurality of first position indicators are positioned along the periphery of the disc, connected to the first part of the shaft and wherein the plurality of second position indicators and the second reference indictor may form a second readout structure, preferably a readout structure in the form of a disc wherein the plurality of second position indicators are positioned along the periphery of the disc, connected to the second part of the shaft.

In an aspect, the invention relates to a force feedback system comprising a torque sensing system as described above.

In a further aspect, the invention relates to an apparatus comprising a force feedback system comprising a torque sensing system as described above.

In an embodiment, the invention may relate to a torsion spring structure for a torque sensing system of an exercise apparatus as described in this application wherein the structure may comprise a rotatable shaft wherein a coupling structure connects a first part of the shaft to a second part of the shaft, and wherein the coupling structure may comprise one or more (spiral) rotary torsion spring structures, compression spring structures and/or a (visco)elastic spring structures.

In an embodiment, the torsion spring structure may be contained in a circular enclosure, the torsion spring including an outer end connected to the outer enclosure, the outer enclosure being connected to the first part of the shaft and the torsion spring including an inner end connected to the second part of the shaft.

In an aspect, the invention relates to a method of controlling a force feedback system of an exercise apparatus. In an embodiment, the method may comprise: a processor receiving at least one signal from an encoder system, the encoder system being configured to measure first position information of a first part of a rotatable shaft and a second position information of a second part of the rotatable shaft of an exercise apparatus, the signal being generated by the encoder system in response to an external force, e.g. a user of the exercise apparatus applying at least a first torque to the first part of the rotatable shaft; the processor using the first second position information and second position information in the at least one encoder signal to compute an angle of twist between the first part and second part of the shaft; and, using the angle of twist to compute a control signal for the force feedback system, the force feedback system including an force generating device rotatable connected to the second part of the rotational shaft; and, the processor transmitting the control signal to the force generating device, the control signal instructing the force generating device to exert a second torque to the second part of the shaft, the second torque being opposite to the first torque. Hence, the invention accurately determines the angle of twist of a rotatable shaft of an exercise apparatus where after the angle of twist is used to by a force feedback system to determine a control signal for an force generating device that generates a braking force exerted on the second part of the shaft that counters the force which an athlete exerts on a first part of the shaft.

The processor of the force feedback system may execute an algorithm representing a kinetic model of the exercise apparatus. Continuously measuring the angle of twist as a function of the force exerted onto (a part of) the exercise apparatus allows the algorithm to accurately model a predetermined exercise apparatus, e.g. an exercise bicycle or a rowing apparatus. This way, a user of the exercise apparatus will be provided with an improved user experience.

More generally, the present invention enables a force feedback system of an exercise apparatus to accurately compute the correct feedback force based on information of the position of a first and second part of a rotating shaft to which a torque is applied by a user of the exercise apparatus. The information may be used in an algorithm representing a kinetic model of the exercise apparatus. The algorithm may also use other information such as the exercise performed, the position of the human body and its specific measurements (tuned to the specific athlete), the equipment used in real life (for instance, type and size of the bike, along with seat height, etc.) to determine a feedback force.

The invention may be used for measuring torques for a rotational shaft of any equipment where varying loads are offered on both ends leading to large rotational (reversible) deformation in said shaft that need to be measured more times per rotation.

In an embodiment, the rotating shaft may include a deformable structure between the first part and second part of the shaft, the deformable structure having a predetermined spring constant. In an embodiment, the deformable structure may be a spring structure such as a torsion spring structure. In an embodiment, the deformable structure may provide a linear correlation between the angle of twist and the first and second torque applied to the shaft.

In an embodiment, the first position information may include a first periodic signal, wherein each period of the first periodic signal is associated with a position of the first part of the rotatable shaft relative to a reference position. In an embodiment, the second position information may include a second periodic signal, wherein each period of the second periodic signal may be associated with a position of a second part of the rotatable shaft relative to a reference position.

In an embodiment, the processor may determine the angle of twist as a function of time on the basis of the first and second periodic signal. In an embodiment, the first and second periodic signal may be a block wave signal or a pulse signal.

In an embodiment, the encoder system may include at least one detector. In an embodiment, the first periodic signal may be generated by the plurality of first position indicators sequentially passing the at least one detector and the second periodic signal may be generated by the plurality of second position indicators sequentially passing the at least one detector.

In an embodiment, the encoder system may include a first readout structure in contact with a first part of the rotatable shaft and a second readout structure in contact with a second part of the rotating shaft.

In an embodiment, the readout structure may comprise a plurality of first position indicators, wherein each first readout element may be associated with an (absolute) position of the first part of the rotatable shaft relative to a reference position and the second readout structure may comprise a plurality of second position indicators, wherein each second readout element may be associated with an (absolute) position of the second part of the rotatable shaft relative to a reference position.

In an embodiment, the first readout structure may further comprise a first reference readout element defining a first reference position of the first part of the shaft and the second readout structure may further comprising a second reference readout element defining a second reference position of the second part of the shaft.

In an embodiment, the first readout structure may include a first disc including the plurality of first position indicators along the periphery of the first disc, each readout element being associated with an absolute angular position of the first part of the shaft; and, the second readout structure includes a second disc including the plurality of second position indicators, preferably optical, electrical (e.g. capacitive) or magnetic position indicators, along the periphery of the second disc, each second readout element being associated with an absolute angular position of the second part of the shaft.

In an embodiment, the plurality of first and second position indicators may be optical position indicators, e.g. an array of slots or the like. These optical position indicators may be detected using an optical detector. In a further embodiment, the first and second position indicators may be magnetic position indicators. Such magnetic position indicators may be detected using a magnetic detector, e.g. a magnetic read-head or the like. In yet another embodiment, the first and second position indicators may be electric (e.g. capacitive) position indicators, which may be detected using a capacitive detector.

In an embodiment, the rotation velocity of the shaft may be between 30 and 600 rotations per minutes (between 0,5 and 10 Hz). In an embodiment, the plurality of first and second position indicators of the first and second readout structure respectively may be arranged to provide between 180 and 540 readout counts per rotation of the shaft.

In an embodiment, the first torque may be associated with a user of the exercise apparatus exerting a force onto a force receiving structure of the exercise apparatus, the force receiving structure being rotatable connected to the first part of the rotatable shaft. In an embodiment, the force receiving structure may include a push mechanism and/or a pull mechanism.

In an embodiment, the encoder system may include at least one detector, the plurality of position indicators sequentially passing a detector, wherein - during the passing of a readout element - the position of a readout element may be measured multiple times by the detector.

In an embodiment, the force feedback system may use a kinematic model of the exercise apparatus to determine a value of the second torque.

In an embodiment, the exercise apparatus may be a stationary bike, e.g. spinning bike. In an embodiment, the rotatable shaft may be part of the back axis of the bike, wherein the first part of the rotatable shaft may be connected to a crank via e.g. a chain.

In an embodiment, the rotatable shaft may include a torsion spring structure in the shape of a mainspring, the main spring being contained in a (circular) enclosure, the main spring including an outer end connected to the outer enclosure, the outer enclosure being connected to the first part of the shaft and the main spring including an inner end connected to the second part of the shaft.

In an embodiment, the encoder system may be further configured to measure third position information for measuring the rotary position of the crank, preferably the processor using the third position information for determining if a user of the exercise apparatus is freeriding.

In an aspect, the invention may also relate to a computer-controlled exercise apparatus. In an embodiment, the exercise apparatus may comprise: a frame comprising a force receiving structure that is rotatable connected to a first part of a rotatable shaft of the exercise apparatus and a force generating device connected to the second part of the rotational shaft; an encoder system configured to measure first position information of the first part of a rotatable shaft and a second position information of the second part of the rotatable shaft, the signal being generated by the encoder system in response to a user of the exercise apparatus applying a force to the force receiving structure, the force exerting a first torque to the first part of the rotatable shaft; and, a force feedback system including an force generating device rotatable connected to the second part of the rotational shaft and a processor of a computer for controlling the force generating device, the processor being configured to: receive at least one signal from an encoder system, the at least one signal including the first position information and the second position information; use the first second position information and second position information in the at least one encoder signal to compute an angle of twist between the first part and second part of the shaft; and, using the angle of twist to compute a control signal for the force feedback system; and, transmit the control signal to the force generating device, the control signal instructing the force generating device to exert a second torque to the second part of the shaft, the second torque being opposite to the first torque.

In an embodiment, the rotating shaft may include a deformable structure, preferably a spring structure such as a torsion spring structure, between the first part and second part of the shaft, the deformable structure having a predetermined spring behaviour, preferably the deformable structure providing a linear correlation between the angle of twist and the first torque applied to the shaft.

In an embodiment, the first position information includes a first periodic signal, preferably a block wave signal or a pulse signal, wherein each period of the first periodic signal is associated with a position of the first part of the rotatable shaft relative to a reference position; and, wherein the second position information includes a second periodic signal, preferably a block wave signal or a pulse signal, wherein each period of the second periodic signal is associated with a position of a second part of the rotatable shaft relative to a reference position, preferably the processor determining the angle of twist as a function of time on the basis of the first and second periodic signal.

In an embodiment, the encoder system may include at least one detector, preferably a first and second detector, a plurality of first position indicators connected to the first part of the shaft and a plurality of second position indicators connected to the second part of the shaft, the first periodic signal being generated by the plurality of first position indicators sequentially passing the at least one detector and the second periodic signal being generated by the plurality of second position indicators sequentially passing the at least one detector.

In an embodiment, the encoder system may include a first readout structure in contact with a first part of the rotatable shaft and a second readout structure in contact with a second part of the rotating shaft, the first readout structure comprising a plurality of first position indicators, each first readout element being associated with an (absolute) position of the first part of the rotatable shaft relative to a reference position and the second readout structure comprising a plurality of second position indicators, each second readout element being associated with an (absolute) position of the second part of the rotatable shaft relative to a reference position.

In an embodiment, the first readout structure may further comprise a first reference readout element defining a first reference position of the first part of the shaft and the second readout structure further comprising a second reference readout element defining a second reference position of the second part of the shaft.

In an embodiment, the first readout structure may include a first disc including the plurality of first position indicators, preferably optical or magnetic position indicators, along the periphery of the first disc, each readout element being associated with an absolute angular position of the first part of the shaft; and, the second readout structure may include a second disc including the plurality of second position indicators, preferably optical or magnetic position indicators, along the periphery of the second disc, each second readout element being associated with an absolute angular position of the second part of the shaft.

In an embodiment, the rotation velocity of the shaft may be between 30 and 600 rotations per minutes (between 0,5 and 10 Hz). In an embodiment, the plurality of first and second position indicators of the first and second readout structure respectively may be arranged to provide between 150 and 600 readout counts per rotation of the shaft.

In an embodiment, the first torque being associated with a user of the exercise apparatus exerting a force onto a force receiving structure of the exercise apparatus, preferably the force receiving structure including a push mechanism and/or a pull mechanism, the force receiving structure being rotatable connected to the first part of the rotatable shaft.

In an embodiment, the encoder system may comprise at least one detector, preferably a first and second detector, the plurality of position indicators sequentially passing a first or second detector, wherein - during the passing - the position of a readout element is measured multiple times by the detector.

In an embodiment the processor of the force feedback system may execute an algorithm representing a kinematic model of the exercise apparatus to determine a value of the second torque.

In an embodiment, the exercise apparatus may be a stationary bike, such as a spinning bike, the rotatable shaft being the back axis of the spinning bike and the first part of the rotatable shaft being connected to a crank, preferably the rotating shaft including a torsion spring structure, preferably the torsion spring structure having the shape of a mainspring, the main spring being contained in a (circular) enclosure, the main spring including an outer end connected to the outer enclosure, the outer enclosure being connected to the first part of the shaft and the main spring including an inner end connected to the second part of the shaft.

in an embodiment, the encoder may comprise an absolute zero trigger, which signals the controller that controls the force generating device that a predefined position is detected. In a further embodiment, a multichannel position encoder may be used to determine the position, preferably the angular position. In more general, any encoder system that is able to determine the position of a first part and a second part of a shaft may be used for determining an angle of twist.

In an embodiment, the rotatable shaft may include a deformable part, the deformable part having a predetermined spring constant, preferably the deformable part providing a linear correlation between the angle of twist and a torque applied to the shaft.

In an embodiment, first encoder may include a first encoder structure connected to the first end and a second encoder structure connected to the second end, a first readout device generating the first encoder signal when the first encoder structure passes the first readout device and a second readout device generating the second encoder signal when the second encoder structure passes the second readout device.

In known exercise apparatus it is common to measure the rotational/translational speed of a resistance unit with a single encoder. In contrast, the current invention a second encoder is added on a different moving part of the apparatus to obtain more information about the type of motion and the phase of the motion. An example is a bicycle where the motion and position of both the crank as the resistance motor are measured to determine and accurately counterbalance freewheeling. Another is that of a cross-country skiing apparatus that measures not only the overall speed of the apparatus, but also the speed and position of each individual leg as it is positioned on the gliding unit.

The invention will be further illustrated with reference to the attached drawings, which schematically will show embodiments according to the invention. It will be understood that the invention is not in any way restricted to these specific embodiments.

Brief description of the drawings

Fig. 1A-1F depict a torque sensing system and a computer-controlled force feedback system using such torque sensing system according to various embodiments of the invention.

Fig. 2A and **2B** depicts a read-out scheme of a torque sensing system according to an embodiment of the invention.

Fig. 3 depicts a flow diagram of a process for controlling a force feedback system according to an embodiment of the invention.

Fig. 4 depicts a schematic of a spinning bike comprising a computer-controlled force feedback system according to an embodiment of the invention.

Fig. 5 depicts a schematic of a part of an encoder system according to an embodiment of the invention.

Fig. 6 depicts a computer-controlled force feedback system according to another embodiment of the invention.

Fig. 7 depicts a computer-controlled force feedback system according to yet another embodiment of the invention.

Fig. 8A-8B depicts a spring structure for a rotatable shaft according to an embodiment of the invention.

Fig. 9 is a block diagram illustrating an exemplary data computing system that may be used for executing methods and software products described in this disclosure.

Detailed description

The embodiments described in this application are aimed at torque sensor systems that are capable of providing a high signal to noise ratio and high frequency feedback at relatively low rotation speeds, e.g. 5 and 20 rotations per minutes. The torque sensor systems are especially suitable for use in a force feedback system, such as an exercise apparatus configured to provide a real-life exercise experience, e.g. an outdoor biking experience or an outdoor rowing experience. The invention aims to provide an accurate measure of a force that is applied to a rotatable shaft comprising a first and second part and a spring structure for mechanically connecting the first of the shaft with the second part of the shaft. An encoder system is configured to measure an angle of twist between the first and second part when a first and second torque is applied to the first and second part respectively. A first readout structure, connected to a first part of the shaft may comprise first position indicators, and a second readout structure connected to the second part of the shaft may comprise second position indicators, wherein the first and second position indicators may be used to determine an absolute rotary position of the first and second part of the rotatable shaft respectively.

For example, when the shaft rotates due to the application of the torques, a reference indicator and position indicators arranged on the readout structure may pass a stationary detector of an encoder system thereby generating a reference signal associated with the reference indicator and a periodic signal, e.g. a square wave type signal, associated with the position indicators. Here, each period of the periodic signal may relate to the detection of a position indicator passing the detector. The position of each position indicator relative to the reference indicator is accurately known. Thus, the reference signal may trigger the encoder system to start counting and determining the passing of subsequent position indicators in time, based on a known or estimated rotation direction. This way, the absolute rotary position of the first and second part of the shaft can be determined as a function of time. After one rotation, a next reference signal may be detected and the encoder may restart the counting process for the next rotation. Thus, during the rotation of the shaft, at each time instance, the position of the first part of the shaft and the position of the second part of the shaft may be determined. Instead of an absolute rotary encoder based on a readout structure comprising (at least one) reference indicator and a plurality of position indictors, an absolute rotary encoder based on coded position indicators may be used. At a time instance, a position indicator in the form of a coded pattern may be read out by a detector, wherein the coded pattern may be directly translated to a position.

This way, the absolute (rotary) position of the first and second part of the shaft may be measured independently and used to determine the angle of twist caused by the torques applied to both parts of the shaft. Measuring the positions of the position indicators and the reference indicators at the first and second part of the shaft may provide an accurate measure of the angle of twist as a function of time. This signal may be processed by a processor in order to determine a control signal for an electrometer that connected to the second part of the shaft. Embodiments and non-limiting implementations of the invention are described hereunder with reference to the figures.

Fig. 1A-1F depict a torque sensing system and a computer-controlled force feedback system using such torque sensing system according to various embodiments of the invention. **Fig. 1A** depicts a torque sensing system comprising rotatable shaft **102** wherein the shaft comprises two parts to which opposing torques can be applied. The resulting torque applied to the shaft may cause to shaft to rotate around its longitudinal axis **104.** The shaft may be part of a mechanical or electro-mechanical apparatus. For example, in an embodiment, the shaft may be part of an exercise apparatus **100**, e.g. a stationary exercise bicycle or a rowing apparatus. In an embodiment, the shaft may be part of an axis, e.g. a rear axis, of a spinning bike, wherein the shaft may be rotatable mounted in a stationary frame (not shown) of the exercise apparatus such that the shaft can rotate around its longitudinal axis.

The shaft of the torque sensing system may include a first part (e.g. a first end) configured to receive a first torque and second part (e.g. a second end) configured to receive a second torque. To that end, the first part may be connected to a force receiving structure, i.e. structure for receiving an external force. For example, in case of a stationary exercise bicycle, a rear gear **106** may be connected to the first part of the shaft so that the shaft is rotatable connected via a chain or a band **108** to a (chain)wheel **110** that is mounted to a rotatable crank **112.** The crank may include crankarms to which pedals **114** are attached. When exerting a force to the force receiving structure, e.g. the pedals, a first torque may be applied to the shaft which may cause the shaft to rotate. The second part of the shaft may be configured to receive a braking force of a force generating device **118** or mechanism. Such force generation device may include any type of means for generating a force, including but not limited to a braking force mechanism based on a mechanical brake, an eddy current brake, a viscous brake, an alternator brake, etc. In an embodiment, the force generation device may be controlled by a computer **120** in order to controllably apply a torque of a predetermined value to the second part of the shaft.

For example, in **Fig. 1A** a force generating device in the form of an alternator may be rotatable connected via e.g. driving band **116** to the second part of the shaft. The force generating device may be controlled by the computer **120** to exert a resistance force or brake force on the second part, which may create a second torque which is opposite to the first torque created by e.g. an external force such as pedal forces. The shaft may include an elastically deformable part (not shown), e.g. a spring structure, that has a predetermined spring behaviour. In particular, part of the shaft may include an elastic spring part that exhibits a reversible torsional elastic deformation that is approximately linear with the torque that is applied to the shaft. The spring structure may be implemented in various ways. For example, the spring structure may include an elastomeric material or a mechanical spring, etc. enabling relative rotary displacement of the two parts of the shaft when a torque is exerted on the shaft.

An example of a reversible deformation of a spring structure is schematically shown in **Fig. 1B**, wherein spring structure **122** represents a spring structure in the form of a shaft which flexible in the rotary direction. In this case no torque is applied, Spring structure **124** depicts the same spring structure in the situation when a torque is applied to both ends. In that case, the structure may exhibit a reversible torsional deformation **126** resulting in a relative rotational displacement $\Delta\alpha$ between the two ends of the spring structure, wherein the relative rotational displacement is referred to as the so-called angle of twist $\Delta\alpha$ **128.** The angle of twist represents a measure of the torque applied to the spring structure, and thus to the shaft of the torque sensing system.

The spring structure **122** may have any suitable form as long as it is capable of providing linear correlation between the torques applied to the shaft and the angle of twist. This is schematically depicted in **Fig. 1C**, wherein a rotary shaft $\mathbf{123_{1,2}}$ includes a first part $\mathbf{123_1}$ and a second part $\mathbf{123_2}$, wherein the first part of the shaft is coupled to the second part of the shaft via a coupling structure **125** for coupling the first shaft to the second shaft may exhibit spring like behaviour in the rotary direction. The coupling structure can have any suitable form and may comprise one or more mechanical rotary springs, compression springs and/or one or more (visco)elastic springs. A detailed embodiment of a spring structure will be discussed hereunder with reference to **Fig. 8.**

In case of an exercise apparatus, such a stationary exercise bicycle, when an athlete starts pedalling, the applied torque will depend on the angular position of the crank and typically exhibits a periodic variation that coincides with one full rotation of the crank. The variation however in one crank rotation may vary greatly depending on a lot of different parameters, including e.g. the position of the crank, the position of the athlete, the muscular build of the athlete. etc. In order to provide an outdoor cycling experience on a spinning bike, the computer need to be able to measure the applied force and fast force variations applied to shaft (and thus the angle of twist $\Delta\alpha$) at very high sampling rates and relatively low rotation speeds for example sample rates > 100 Hz at approx. 10 rpm, so that the angle of twist accurately follows the applied force during pedalling as a function of time.

To that end, a first readout structure **130** may be connected to the first side of the shaft and a second readout structure **132** may be connected to the second side of the shaft. The first and second readout structures may be part of an encoder system **136** for determining first position information associated with an (absolute) rotary position of a plurality of first position indicators, e.g. slots, of the first readout structure and for determining second position information associated with the position of a plurality of second position indicators of the second readout structure. In an embodiment, the encoder system may be configured as a rotary encoder system. In embodiment, the encoder system may include readout structures in the form a disc connected to the shaft that is provided with position indictors **134** and a reference indicator **135**. Each of the position indicators may have predetermined dimensions and/or shapes. The position indicators may be provided along a circular path on the disc, e.g. a circular path at the periphery of the disc.

The encoder system may be implemented in different ways, e.g. in an embodiment, the encoder system may include one or more optical encoders, wherein the readout structure may include a plurality of position indicators in the form of one or more slots, e.g. windows. A readout device may include an optical source and at least one optoelectronic detector. In another embodiment, the encoders may be magnetic encoders, wherein the readout structure may include a plurality of position indicators in the form of of magnetic elements. Further, the readout device may include at least one magnetic head.

In an embodiment, the readout structure may include a reference element, e.g. a window or a magnetic element, that has dimensions or physical properties (e.g. magnetic field strength) that are different from the regular position indicators.

In a further embodiment the readout device may comprise one or more camera's. In that case, one or more position indicators may be associated with a code, e.g. a barcode or a QR code representing a unique (sequence) number, which may be used to link a position indicator to a position. For example, in an embodiment, the position indicators may be configured as coded slots which may be read out optically or magnetically. The position indicators are coded such that each position indicator can be associated with a different code which in turn may be related to an absolute rotary position, using e.g. a lookup table or a mathematical function.

The coding one or more position indicators enable the computer to determine a rotary position for each position indicator of the readout structure. Coding can be based on one indicator (e.g. a reference indicator) indicating the absolute position of one position indicator which may be used to derive the absolute positions of the other position indicators. Alternatively, a plurality of position indicators may be coded so that each of the position indicators can be directly linked to a position.

An optical system may be used to enable the camera to monitor one or more encoders. For example, an optical system may be configured to arrange both encoders in the in the field of view a digital camera, so that the position indicators of both readout structures can be readout simultaneously by the digital camera.

Known examples of encoder readout systems are depicted in **Fig. 1D** and **1E.** As shown in **Fig. 1D,** the readout may include a light source **140**, e.g. a laser diode, which emits light towards the readout structure, in this example position indictors in the form of slots or windows in rotatable encoder disc **142**, which is connected to a rotatable shaft. An optical structure, e.g. refractive elements or the like (not shown) may be used to focus the light as a light beam onto the slots. During rotation (when the light source is positioned in line with the slots in the encoder disc) the light beam of the light source will pass through the encoder disc and may be detected by a light detector **144.** The light beam will be blocked if the light source is positioned between to windows. Hence, when the encoder disc rotates, the light detector will be periodically exposed by a light signal. This way, a signal is generated by the light detector in the form of a periodic signal, e.g. a block wave or a pulse signal, wherein the frequency of the signal may depend on the number of readout structures (the number of slots) and the rotational speed of the shaft. As will be described hereunder in more detail, an additional reference indicator associated with an absolute rotary position of the shaft may be used to relate each of the position indicators on the disc to an absolute position. Further, the encoder scheme depicted in **Fig. 1D** may be easily extended to a so-called quadrature encoder in which two detectors positioned relative to each other so that the second detector detects a second periodic signal that is 90 degrees phase shifted. This known encoder scheme may be used to determine also the rotation direction.

Thus, the detectors of the torque sensing system depicted in **Fig. 1A** may generate a signal when position indicators pass the detector. In an embodiment, at least one of the position indicators may be configured as a reference indicator which is configured to provide a different response than the other position indicators. In that case, the signal generated by the readout device may include a reference signal which can be used as a reference for determining the position of the other position indicators. Thus, when the reference signal is detected by the computer, it knows the absolute rotary position the encoder disc. Then, each subsequent detector signal that signals the passing of a position indicator can counted by a counter. The number of detected position indicators relative to the reference signal may be used to determine the absolute position. Such encoder system is also referred to as an incremental rotary encoder. In another embodiment, the reference indicator may be implemented separately from the position indicators. For example, a separate detector may detect the reference indicator and generate a separate reference signal for signalling the detection of a reference indicator passing the detector.

Fig. 1E depicts a so-called absolute encoder readout system including a rotatable shaft **154** connected to an encoder disc **156** which can be optically read. Different circular slot patterns may be arranged around the shaft, wherein each circular slot pattern can be readout by an optical sensor, each optical sensor including a light source **150** and a light detector **152.** An optical stop **154** and optical elements such as refractive elements (not shown) may be used to position a light beam on one of the circular slot patterns. The circular slot patterns are arranged such that the output signals **156** of the optical sensors may form a digital representation for a position. For example, the four circular slot patterns in **Fig. 1E** may generate four periodic block functions of different period so that the signal amplitudes at a particular time instance directly translates into a binary value. The resolution of the encoder is determined by the bit resolution (e.g. 8 bits would give 256 positions). Further, by measuring two or more position indicators also the rotary direction can be determined.

Fig. 1F depicts a torque sensing system which is similar to the system depicted in **Fig. 1A** with the exception that the first readout structure **130** may be part of the crank. This way, the first readout structure is rotatable connected to the first part of the rotatable shaft via a chain or a band **108** connecting the chain wheel of the crank with a rear gear connected to the first part of the shaft. More generally, the first and/or second readout structures may be directly connected to the shaft or indirectly via a gearing system or any other suitable transmission system. Furthermore, the position indicators described with reference to the embodiments in this application may be realized in any suitable form as long as there is a direct relation between the position of the rotatable shaft and the position of position indicators that are monitored by a detector. For example, instead of slots or markers on a disc connected to a part of the shaft, chain links of a chain connecting the crank with the read gear may be used as position indicators

Typical values e.g. the rotation velocity of the shaft may be between 5 and 20 rotations per minutes. Further, the plurality of first and second position indicators of the first and second readout structure respectively may be arranged to provide between 150 and 600 readout counts per rotation of the shaft. This way, the position may be determined very accurately, even at low rotation frequencies.

The encoder system may sample the detector signal a large number of times. For example, sample frequencies higher than 100 Hz at relatively low rotation speeds (10 rpm) can be achieved. Such high sample frequencies are necessary to accurately determine the angle of twist $\Delta\alpha$ and fast variations in the angle of twist in the shaft due to changes in forces applied by the user to a part, e.g. the pedals, of the exercise device.

When the exercise apparatus is in use, the encoder system **136** may generate at least one (encoder) signal **137** that includes first and second position information associated with the first and second readout structure respectively. The position information may have form of one or more periodic signals, e.g. one or more block wave signals or pulse signals. In an embodiment, during readout, the passage of a reference indicator (e.g. a reference window of the readout structure) may be detected generating a reference signal. The reference signal may be used to identify each subsequent position indicator that passes the detector. After each full rotation of the shaft, a new reference signal may be generated. The reference signal may be coded into the encoder signal that is sent to the computer. The reference signal may trigger the computer to start counting the number of (block wave) periods in the encoder signal, wherein each period is associated with a position indicator passing the detector. When a torque is applied to both ends of the shaft, the shaft will start to rotate, and, in response, the encoder system may start generating first and second position information associated with both readout structures. The computer **120** may determine the angle of twist $\Delta\alpha$ caused by the torque based on the rotary position of the first and second part of the shaft as determined by the encoder system. In particular, the angel of twist may be the difference between the first rotary position and the second rotary position at a certain time instance.

In an embodiment, the angle of twist may be used in an algorithm representing a kinematic model of the exercise apparatus. A known kinematic model is described in US7,833,135. Based on the model, the computer may determine a control signal or a feedback **121** for the force generating device **118** which may generate a brake force that partly counters the force that is applied by the user. In case of an exercise apparatus, the brake force may be experienced by a user of the exercise apparatus as a resistance. The resistance force may be controlled at a time scale that includes variations in the torque due to variations in the force applied to the exercise apparatus by the user.

The resulting torque that is applied to the shaft at each time instance may introduce a reversible torsional deformation in the spring structure of the shaft. The reversible torsional deformation may cause a relative rotational shift between the position indicators of the readout structures connected to the first and second part of the shaft. Because the encoder system is able to measure an absolute rotary position for the first and second part of the shaft, the relative shift between the position indicators may be larger than the rotational angle between two subsequent position indicators of the first readout structure or the second readout structure. In particular, the spring structure may be configured to provide a maximum angle of twist which is larger than the rotary angle between two subsequent position indicators of the first and second readout structure.

A reference indicator or coded position indicators may allow the computer to determine an absolute position of a position indicator that passes the detector. Thus, the spring behaviour of the spring structure, e.g. the spring constant, may be configured to provide a relative shift in the rotary position between the first and second readout structure between -20 and 20 degrees, preferably -10 and 10 degrees, in response to the application of an external force (or external forces) on the shaft. This way, a large signal to noise ratio can be obtained.

Therefore, the computer may determine the angle of twist $\Delta\alpha$ for many time instances during the passing of the position indicators (e.g. a window or a magnetic element) by determining for each time instance a difference between an absolute rotary position of the first encoder disc and an absolute rotary position of the second encoder disc.

Fig. 2A and **2B** depicts a read-out scheme of a torque sensing system according to an embodiment of the invention. As described with reference to **Fig. 1**, the angle of twist $\Delta\alpha$ can be calculated by the computer by determining the rotary position of the first part of the shaft on the basis of the first position information in the encoder signal and the rotary position of the second part of the shaft on the basis of the second position information in the encoder signal. In an embodiment, in order to accurately determine the rotary positions of both encoder discs at each point in time, the readout of the encoder may be synchronized. Thus, the computer continuously reads out both encoder signals at high frequencies, i.e. 100 Hz or higher, and determines rotary positions of both rotary discs. Based on the rotary positions the computer may determine the angle of twist as a function of time wherein the angle of twist may be larger than the angle between two subsequent position indicators.

Fig. 2A depicts part of an encoder signal of the first encoder readout structure **202** connected to a first part of a rotating shaft. The encoder signal includes a first signal $\mathbf{203_1}$ representing a reference signal and a second signal including a period block wave signal. The reference signal is generated by a reference indicator $\mathbf{205_1}$ of passing the detector $\mathbf{207_1}$. The periodic block wave signal may include a first transition **204** from a high sensor signal to a low sensor signal (going form a part where the optical signal is detected to a part wherein the optical signal is block) and a second transition **206** going from a low signal (optical signal blocked) to a high signal (optical signal detected).

Similarly, **Fig. 2B** depicts part of an encoder signal of the second encoder readout structure **202** connected to a second part of the rotating shaft. The encoder signal includes a first signal **203_2** representing a reference signal and a second signal including a period block wave signal. The reference signal is generated by a reference indicator **205_2** of passing the detector **207_2**. The periodic block wave signal may include a first transition **210** from a high sensor signal to a low sensor signal (going form a part where the optical signal is detected to a part wherein the optical signal is block) and a second transition **212** going from a low signal (optical signal blocked) to a high signal (optical signal detected).

The angular positions of the transitional regions of the encoder disc are known very accurately. Moreover, the transitions in the encoder signal can be detected very precisely by the computer. Thus, as shown in **Fig. 2A** and **2B**, each transition in the encoder signal can be accurately linked to a left or right edge of a window in the encoder disc. The rotary positions (e.g. α_2^1 and α_2^1 in **Fig. 2A**) of the edges can be very accurately determined as well as the distance Δx between edges. For example, the computer may determine that at a first time instance the first encoder detects the forth position indicator (i.e. four block wave periods relative to the first reference signal) while the second encoder detects the second position indicator (i.e. two block wave periods relative to the second reference signal). This information allows the computer to accurately determine a torsional angel $\Delta\alpha$ at an arbitrary time instance t_i.

Fig. 2A depicts a first encoder signal depicting a first transition **204** at time instance t_1^1 associated with angular position α_1^1 and a second transition **206** at time instance t_2^1 associated with angular position α_2^1, wherein the distance between the first and second transition is denoted as Δx^1. Based on this information, the angular position of the encoder disc at t_i can be predicted by the following equation: $\alpha_i^1(t_i) = \alpha_2^1(t_2^1) + v^1(t_i - t_2^1)$ wherein $v^1 = \Delta x^1/(t_1^1 - t_2^1)$. Similarly, **Fig. 2B** depicts a second encoder signal depicting a first transition **210** at time instance t_1^2 associated with angular position α_1^2 and a second transition **212** at time instance t_2^2 associated with angular position α_2^2, wherein the distance between the first and second transition is denoted as Δx^2. Based on this information, the angular position of the second encoder disc at t_i can be predicted by the following equation: $\alpha_i^2(t_i) = \alpha_2^2(t_2^2) + v^2(t_i - t_2^2)$ wherein $v^2 = \Delta x^2/(t_1^2 - t_2^2)$. This way, the torsional angel can be determined: $\Delta\alpha(t_i) = \alpha_i^2(t_i) - \alpha_i^1(t_i) + \alpha_o$ at any time instance t_i. As the encoder system can determine absolute rotary positions, the scheme works for both small and large torsional angels at high accuracy. Here, the diameter of the encoder disc and the number of position indicators, e.g. slots or (coded) markers, on the encoder discs may determine the resolution of the readout. The more position indicators, the higher the resolution of the rotary position.

Fig. 3 depicts a flow diagram of a process for controlling a force feedback system according to an embodiment of the invention. As described with reference to **Fig. 1** and **2**, the force feedback system may include a computer receiving information from the encoder system connected to an exercise apparatus and transmitting control information to a force generating device connected to the exercise apparatus. A processor of the computer may execute a program which includes a first step **302** wherein the computer receives at least one signal from an encoder system, wherein the encoder system is configured to measure first absolute position information of a first part of a rotatable shaft and second absolute position information of a second part of the rotatable shaft, the signal being generated by the encoder system in response to a first torque exerted to the first part of the rotatable shaft. Here, first and second absolute position information may be generated by the encoder system by reading out a first readout structure in contact with a first part of a rotating shaft and the second encoder signal may be generated reading out a second readout structure in contact with a second part of a rotating shaft of the exercise apparatus. The first torque be applied to the first part, may be associated with a user of the exercise apparatus exerting a force onto a part of the exercise apparatus, e.g. a crank, wherein the part of the exercise apparatus may be rotatable connected, e.g. via a chain, a band or any other suitable transmission system, to the first part of the shaft.

Then, in a second step **304**, the computer may use the first and second absolute position information to compute an angle of twist between the first part and second part of the shaft; and use the angle of twist to compute a control signal for a force feedback system, the force feedback system including a force generating device connected to the second part of the rotational shaft. The computer may use the angle of twist as an input to a kinetic model of the exercise apparatus in order to determine a suitable brake force that needs to be applied to the second part of the shaft.

Thereafter, in a third step **306** the computer may transmit the control signal to the force generating device, wherein the control signal may control the force generating device to exert a second torque to the second end of the shaft, wherein the second torque may be opposite to the first torque.

Fig. 4 depicts a schematic of a part of a spinning bike comprising a computer-controlled force feedback system according to an embodiment of the invention. In particular, this figure depicts the side face of part of an exercise apparatus **400**, in this case a stationary bike, comprising a frame 402 supporting a force receiving structure, i.e. the force receiving structure in the form of a force crank **404** with pedals **406**, wherein the crank is rotatable connected via a chain **408** to a back gear **415**. Here, the back gear is connected to a first part (e.g. a first end) to a rotatable shaft. The first part of the shaft is further connected to a first encoder disc **410** comprising position indicators **412**, e.g. slots, that are arranged along the periphery of the first encoder disc. A detector **414** is located at the position of the position indicators so that when the apparatus is in use, the first encoder disc will rotate in reaction to a force exerted on the first part of the shaft and the position indicators sequentially pass the detector, which detects the passing slots. This way, the detector may generate a periodic square wave type signal as described with reference to **Fig. 1** and **2** representing the rotary position of the first encoder disc as a function of time. The position indicators may include a reference readout element **416** which provides a reference signal. The reference signal may be used by the computer to detect the start of a new rotation and provides a reference position relative to the positions of position indicators. A force generating device **420** is rotatable connected via a band or a chain **408** to a second part of the shaft, wherein the second part of the shaft is connected to a second rotary disc, which can be readout by a second detector (not shown).

Fig. 5 depicts a schematic of another side view of the spinning bike as described with reference to **Fig. 4.** This figure illustrates the arrangement of the rotatable shaft **502** comprising a first part **501**$_1$ and a second part **501**$_2$. The shaft may comprise a deformable spring structure between the first and second part. Further, the shaft is rotatable mounted to the frame of the stationary bike and includes a gear unit **504** at a first end of the shaft and a driving wheel **506** at the second end of the shaft. A first encoder disc **508**$_1$ including a plurality of first position indicators is connected to the first part of the shaft and a second encoder disc **508**$_2$ comprising a plurality of second position indicators is connected to the second part of the shaft. When a force is exerted on the first part of the shaft, the shaft starts to rotate and the first and second encoder discs are read out by a first detector **510**$_1$ and second detector **510**$_2$ respectively, wherein a periodic signal generated by the first detector represents location information of the first part of the shaft and the periodic signal generated by the second detector represents location information of the second part of the shaft. Here, the driving wheel may be rotatable connected via a driving belt **512** to a driving wheel of a computer-controlled electronic motor **514**, which is configured to produce a brake force which will be applied as a second torque to the second part of the shaft. The shaft - encoder arrangement provides a compact design which can be easily integrated in a conventional exercise apparatuses, such as an exercise bicycle.

Fig. 6 and **7** depict computer-controlled force feedback systems for an exercise apparatus according to various embodiments of the invention. In particular, both **Fig. 6** and **7** depict part of exercise apparatus comprising a computer **602,702** connected to an encoder system **602,702** that is configured to read out rotary positions of a first part **606_1,706_1** and second part **602_2,702_2** of a rotatable shaft, wherein the rotatable shaft comprises a spring structure of a predetermined spring behaviour, e.g. a predetermined spring constant. If a first torque is applied to the first part of the rotatable shaft, the encoder system generates position information **608,708** of the first and second part of the shaft and the computer uses this information in order to determine an angle of twist of the shaft. The computer may use the angle of twist to control a force generating device **612,712** by sending a feedback signal **610,710** to the force generating device to generate a second torque to the second part of the shaft. These elements are described in detail with reference to **Fig. 1-3.** Additionally, **Fig. 6** and **7** depict variants wherein the computer-controlled force feedback system includes a third encoder configured to measure third position information. In this case, the third position information may be associated with a position of a body part of the user of the exercise apparatus. For example, **Fig. 6** depicts a variant wherein the exercise apparatus is a stationary exercise bike, wherein the rotatable shaft is part of the rear axis of the bike and wherein the first part of the shaft is connected to a gear, which is connected via a chain **612** to the chainwheel of the crank **614** of the bike. The third encoder **616** may have a readout structure in the form of a disc comprising position indicators positioned along periphery of the disc, wherein each position indicators determines a rotary position of the crank relative to a reference position of the crank. Thus, the third encoder may generate third position information **618** in the form of a periodic signal that is generated by a detector of the third encoder sequentially reading the position indicators when the user uses the exercise bike. The third position information may be used by the computer to determine the position of the crank and the pedals **620** and thus the position of the feet of the user during the exercise. In an embodiment, the computer may use the third position information for determining if a user of the exercise apparatus is freeriding. For example, the processor may instruct the force generating device to adjust the second torque based on the third position information if the third position information signals the processor that the user of the exercise apparatus is freewheeling.

In a similar way, **Fig. 7** depicts a computer-controlled force feedback system for a rowing exercise apparatus. As shown in this figure, the rotatable shaft may be mounted on the frame **714** of the exercise apparatus. The frame may include a slidable seat **716** and a footrest structure connected to the frame. The first part of the shaft may be connected to a rotary mechanism including a chain or a cord connected to a handle **720** (representing the oar). The rotary mechanism of the rowing exercise apparatus is configured to enable a user to exercise strokes wherein each stroke includes a catch position (the start position), a drive phase wherein the user generates power up to the release (the end of the stroke) and a recovery phase wherein the rower slides back to the catch position. During the drive phase, the user exerts a force onto the first part of the shaft by a pull mechanism, during this phase the encoder system may provide position information of the first and second part of the shaft. Further, the third encoder may determine third position information **718** representing the position of the user during stroke actions to the computer and the computer will use this information to control a force generating device to exert a second torque on the shaft that is opposite to the first torque. Hence, the third encoder may be configured to determine for example the position of the slidable seat using a linear position encoder. The computer may use the position of the seat to determine if the user is in a catch, drive, release or recovery position and to control the force generating device accordingly.

Fig. 8A and **8B** depict a first and second cross sectional view of a shaft - encoder structure according to an embodiment of the invention. In particular, **Fig. 8A** depicts an example of a rotatable shaft **800** including a torsion spring structure **802**, preferably a spiral spring structure, between a first part $\mathbf{801_1}$ and second part $\mathbf{801_2}$ of the shaft, wherein a first encoder disc $\mathbf{808_1}$ and second encoder disc $\mathbf{808_2}$ are connected to the first and second part of the shaft respectively. At the first part, the shaft may be further connected to a gear **804**, for rotatable connecting the shaft to e.g. a crank. The second part of the shaft may be connected to a gear or a driving wheel **806** for connecting the second part to a force generating device. Thus, the torsion spring structure connects the first part of the shaft to the second part of the shaft, so that if a torque is applied to the first and second part the spring structure may cause an angle of twist between the first and second part. The shaft - encoder structure depicted in **Fig. 8** is similar to the structure described with reference to **Fig. 5** with the exception that the torsion spring has the shape of a spiral torsion spring **803**, sometimes also referred to as a mainspring, e.g. a metal mainspring.

As shown in **Fig. 8B**, the spiral torsion spring may be contained in a (circular) enclosure **807**. The spiral torsion spring may include an outer end $\mathbf{805_1}$ connected to the outer enclosure wherein the outer enclosure may be connected to the first part $\mathbf{801_1}$ of the shaft. For example, as shown in **Fig. 8A**, one side of the outer enclosure of the main spring may be fixed to the first encoder disc $\mathbf{808_1}$ that is connected to the first part of the shaft. Further, the spiral torsion spring may include an inner end **805_2** connected to the second part **801_2** of the shaft. The spring arrangement of **Fig. 8A** and **8B** provides a particular compact design wherein the spiral torsion spring can be designed such that it has a spring behaviour, e.g. a spring constant, for determining an angel of twist within a predetermined range. In one embodiment, a range between -20 and 20 degrees is selected. In another embodiment, a range between -10 and 10 degrees is selected.

Fig. 9 is a block diagram illustrating an exemplary data processing system that may be used in as described in this disclosure. Data processing system **900** may include at least one processor **902** coupled to memory elements **904** through a system bus **906.** As such, the data processing system may store program code within memory elements **904.** Further, processor **902** may execute the program code accessed from memory elements **904** via system bus **906.** In one aspect, data processing system may be implemented as a computer that is suitable for storing and/or executing program code. It should be appreciated, however, that data processing system **900** may be implemented in the form of any system including a processor and memory that is capable of performing the functions described within this specification.

Memory elements **904** may include one or more physical memory devices such as, for example, local memory **908** and one or more bulk storage devices **910.** Local memory may refer to random access memory or other non-persistent memory device(s) generally used during actual execution of the program code. A bulk storage device may be implemented as a hard drive or other persistent data storage device. The processing system **1000** may also include one or more cache memories (not shown) that provide temporary storage of at least some program code in order to reduce the number of times program code must be retrieved from bulk storage device **910** during execution.

Input/output (I/O) devices depicted as input device **912** and output device **914** optionally can be coupled to the data processing system. Examples of input device may include, but are not limited to, for example, a keyboard, a pointing device such as a mouse, or the like. Examples of output device may include, but are not limited to, for example, a monitor or display, speakers, or the like. Input device and/or output device may be coupled to data processing system either directly or through intervening I/O controllers. A network adapter **916** may also be coupled to data processing system to enable it to become coupled to other systems, computer systems, remote network devices, and/or remote storage devices through intervening private or public networks. The network adapter may comprise a data receiver for receiving data that is transmitted by said systems, devices and/or networks to said data and a data transmitter for transmitting data to said systems, devices and/or networks. Modems, cable modems, and Ethernet cards are examples of different types of network adapter that may be used with data processing system **950**.

As pictured in **FIG. 9**, memory elements **904** may store an application **918**. It should be appreciated that data processing system **900** may further execute an operating system (not shown) that can facilitate execution of the application. Application, being implemented in the form of executable program code, can be executed by data processing system **900**, e.g., by processor **902**. Responsive to executing application, data processing system may be configured to perform one or more operations to be described herein in further detail.

In one aspect, for example, data processing system **900** may represent a client data processing system. In that case, application **918** may represent a client application that, when executed, configures data processing system **900** to perform the various functions described herein with reference to a "client". Examples of a client can include, but are not limited to, a personal computer, a portable computer, a mobile phone, or the like. In another aspect, data processing system may represent a server. For example, data processing system may represent an (HTTP) server in which case application **918**, when executed, may configure data processing system to perform (HTTP) server operations. In another aspect, data processing system may represent a module, unit or function as referred to in this specification.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description of the present invention has been presented for purposes of illustration and description, but is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the invention. The embodiment was chosen and described in order to best explain the principles of the invention and the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

CONCLUSIES

1. Een draaimoment-meetsysteem, omvattend:

een draaibare schacht met een eerste deel en een tweede deel, welke schacht een veerstructuur omvat tussen het eerste en tweede deel;

een eerste uitleesstructuur verbonden met het eerste deel die eerste positie-indicatoren omvat en een tweede uitleesstructuur verbonden met het tweede deel die tweede positie-indicatoren omvat;

een encodeersysteem ingericht om een eerste absolute draaipositie van het eerste deel van de schacht te meten gebaseerd op de eerste positie-indicatoren en een tweede absolute draaipositie gebaseerd op de tweede positie-indicatoren;

waarin in reactie op een externe kracht op het eerste en/of tweede deel, het verschil tussen een eerste en tweede absolute draaipositie, gemeten door het encodeersysteem, een verdraaiingshoek bepaalt.

2. Draaimoment-meetsysteem volgens conclusie 1 waarin de veerstructuur ingericht is om een maximum verdraaiingshoek te verschaffen die groter dan de draaihoek tussen twee opeenvolgende positie-indicatoren van de eerste en tweede uitleesstructuur.

3. Draaimoment-meetsysteem volgens conclusie 1 of 2 waarin de veerstructuur ingericht is om een verdraaiingshoek te verschaffen tussen -20 en 20 graden, bij voorkeur tussen -10 en 10 graden.

4. Draaimoment-meetsysteem volgens een der conclusies 1-3 waarin de veerstructuur een torsieveer omvat, bij voorkeur een spiraal-torsieveer.

5. Draaimoment-meetsysteem volgens een der conclusies 1-4 waarin de eerste uitleesstructuur ten minste een eerste referentie-indicator omvat, waarbij het encodeersysteem bovendien ingericht is om een absolute draaipositie van de eerste referentie-indicator te bepalen en om een absolute positie van ten minste één van de veelheid aan positie-indicatoren te bepalen gebaseerd op de absolute positie van de eerste referentie-indicator.

6. Draaimoment-meetsysteem volgens een der conclusies 1-4 waarin elk van de eerste positie-indicatoren geassocieerd is met een unieke code (e.g. één of meer markeringen, getallen, symbolen, patronen, gecodeerde sleuven of combinaties daarvan), waarbij het encodeersysteem bovendien ingericht is om een absolute draaipositie te bepalen voor elke positie-indicator gebaseerd op de geassocieerde unieke code, welk encodeersysteem bij voorkeur een geheugen heeft dat een opzoektabel omvat met de unieke codes en draaiposities van de positie-indicatoren of een functiemodule heeft die een functionele relatie verschaft tussen de unieke codes en draaiposities van de positie-indicatoren.

7. Draaimoment-meetsysteem volgens een der conclusies 1-6 waarin de eerste uitleesstructuur een schijf bevat verbonden met het eerste deel van de schacht waarin de eerste positie-indicatoren gepositioneerd zijn langs één of meer ronde paden op de eerste schijf; en/of, waarin de tweede uitleesstructuur een tweede schijf bevat verbonden met het tweede deel van de schacht, waarin de tweede positie-indicatoren gepositioneerd zijn langs één of meer ronde paden op de tweede schijf.

8. Draaimoment-meetsysteem volgens een der conclusies 1-7 waarin het encodeersysteem één of meer detectoren bevat voor het detecteren van de positie-indicatoren en/of

één of meer beeldsensoren voor de beeldvorming van de positie-indicatoren, welke één of meer detectoren bij voorkeur ten minste één bevatten van: een optische detector, een magnetische detector en/of een capacitieve detector.

9. Kracht-terugkoppelsysteem voor een trainingstoestel, omvattend:

een draaimoment-meetsysteem volgens een der conclusies 1-8;

een krachtopwekkend apparaat, verbonden met het tweede deel van de draaibare schacht;

een computer, omvattend een processor ingericht voor:

- in reactie op een eerste draaimoment uitgeoefend op het eerste deel van de draaibare schacht, het van het draaimoment-meetsysteem ontvangen van eerste absolute-positie-informatie van het eerste deel van de draaibare schacht en tweede absolute-positie-informatie van het tweede deel van de draaibare schacht;
- het gebruiken van de eerste en tweede absolute-positie-informatie om een verdraaiingshoek te berekenen tussen het eerste deel en tweede deel van de schacht; en,
- het berekenen van een regelsignaal voor het krachtopwekkende apparaat, welk regelsignaal het krachtopwekkend apparaat aanstuurt om een tweede draaimoment uit te oefenen op het tweede uiteinde van de schacht, welk tweede draaimoment tegengesteld is aan het eerste draaimoment.

10. Een computergestuurd trainingstoestel omvattend:

een frame; een draaibaar op het frame bevestigde schacht;

ten minste één krachtontvangende structuur die draaibaar verbonden is met een eerste deel van de draaibare schacht; en, een krachtopwekkend apparaat verbonden met het tweede deel van de draaibare schacht;

een encodeersysteem ingericht om eerste absolute positie-informatie te meten van het eerste deel van de draaibare schacht en tweede absolute positie-informatie te meten van het tweede deel van de draaibare schacht, waarbij de eerste en tweede positie-informatie gegenereerd wordt door het encodeersysteem in reactie op het door een gebruiker van het trainingstoestel uitoefenen van een kracht op de krachtontvangende structuur, welke kracht een eerste draaimoment uitoefent op het eerste deel van de draaibare schacht; en,

een kracht-terugkoppelsysteem die een computergestuurd krachtopwekkend apparaat bevat dat draaibaar verbonden is met het tweede deel van de schacht, en een processor van een computer ingericht om een verdraaiingshoek te bepalen tussen het eerste en tweede deel van de schacht op basis van de eerste en tweede absolute positie-informatie en om het krachtopwekkend apparaat aan te sturen om een tweede draaimoment uit te oefenen op het tweede deel van de schacht, gebaseerd op de eerste en tweede draaimoment, welk tweede draaimoment tegengesteld is aan het eerste draaimoment.

11. Een computergestuurd trainingstoestel volgens conclusie 10, bovendien omvattend:

een eerste uitleesstructuur verbonden met het eerste deel die eerste positie-indicatoren omvat en een tweede uitleesstructuur verbonden met het tweede deel die tweede positie-indicatoren omvat;

waarin het encodeersysteem ingericht is om eerste absolute-positie-informatie te meten, gebaseerd op de eerste positie-indicatoren en de tweede absolute-positie-informatie gebaseerd op de tweede positie-indicatoren.

12. Een computer-bestuurbaar trainingstoestel volgens conclusies 10 of 11, waarin het trainingstoestel een stationaire trainingsfiets is, waarbij de draaibare schacht

de achteras is van de trainingsfiets of draaibaar verbonden is met de achteras van de trainingsfiets, en het eerste deel van de draaibare schacht verbonden is met een versnelling, waarbij een transmissiesysteem, dat bij voorkeur een ketting of een band bevat, de versnelling met een trapas verbindt, waarbij de draaibare schacht bij voorkeur een torsieveer-structuur bevat in de vorm van een spiraal-draaiveer, welke spiraal-draaiveer vervat is in een (ronde) omhulling, waarbij de spiraal-draaiveer een buitenste uiteinde bevat verbonden met de buitenste omhulling, welke buitenste omhulling verbonden is met het eerste deel van de schacht en de spiraal-draaiveer een binnenste uiteinde bevat verbonden met het tweede deel van de schacht.

13. Een computer-bestuurbaar trainingstoestel volgens een der conclusies 10-12, waarin de processor een algoritme gebruikt gebaseerd op een kinematisch model van het trainingstoestel om een waarde te bepalen van het tweede draaimoment met gebruik van de verdraaiingshoek als invoerinformatie.

14. Een torsieveerstructuur voor een draaimoment-meetsysteem van een trainingstoestel, welke torsieveerstructuur een draaibare schacht omvat en een koppelstructuur die een eerste deel van de schacht verbindt met een tweede deel van de schacht, welke koppelstructuur één of meer (spiraal) draaitorsieveerstructuren, drukveerstructuren en/of (visco)elastische veerstructuren omvat, waarbij de torsieveerstructuur bij voorkeur vervat is in een ronde omhulling, waarbij de torsieveer een buitenste uiteinde bevat verbonden met de buitenste omhulling, welke buitenste omhulling verbonden is met het eerste deel van de schacht en de torsieveer een binnenste uiteinde bevat verbonden met het tweede deel van de schacht.

15. Een werkwijze voor het aansturen van een kracht-terugkoppelsysteem van een trainingstoestel omvattend:

het door een processor ontvangen van ten minste één signaal van een encodeersysteem, welk encodeersysteem ingericht is om eerste absolute-positie-informatie te meten van een eerste deel van een draaibare schacht en tweede absolute-positie-informatie van een tweede deel van de draaibare schacht van een trainingstoestel, waarbij het signaal gegenereerd wordt door het encodeersysteem in reactie op een externe kracht, e.g. een gebruiker van het trainingstoestel die ten minste een eerste draaimoment uitoefent op het eerste deel van de draaibare schacht;

het door de processor gebruiken van eerste positie-informatie en tweede positie-informatie in het ten minste één encodeersignaal om een verdraaiingshoek te berekenen tussen het eerste deel en het tweede deel van de schacht; en, het gebruiken van de verdraaiingshoek om een regelsignaal te berekenen voor het kracht-terugkoppelsysteem, welk kracht-terugkoppelsysteem een krachtopwekkend apparaat bevat dat draaibaar verbonden is met het tweede deel van de draaibare schacht; en,

het door de processor verzenden van het regelsignaal naar het krachtopwekkend apparaat, welk regelsignaal het krachtopwekkend apparaat instrueert om een tweede draaimoment uit te oefenen op het tweede deel van de schacht, welk tweede draaimoment tegengesteld is aan het eerste draaimoment.

16. Computerprogrammaproduct omvattend gedeelten softwarecode, geconfigureerd om, wanneer gedraaid in het geheugen van een computer, de stappen van de werkwijze volgens conclusie 15 uit te voeren.

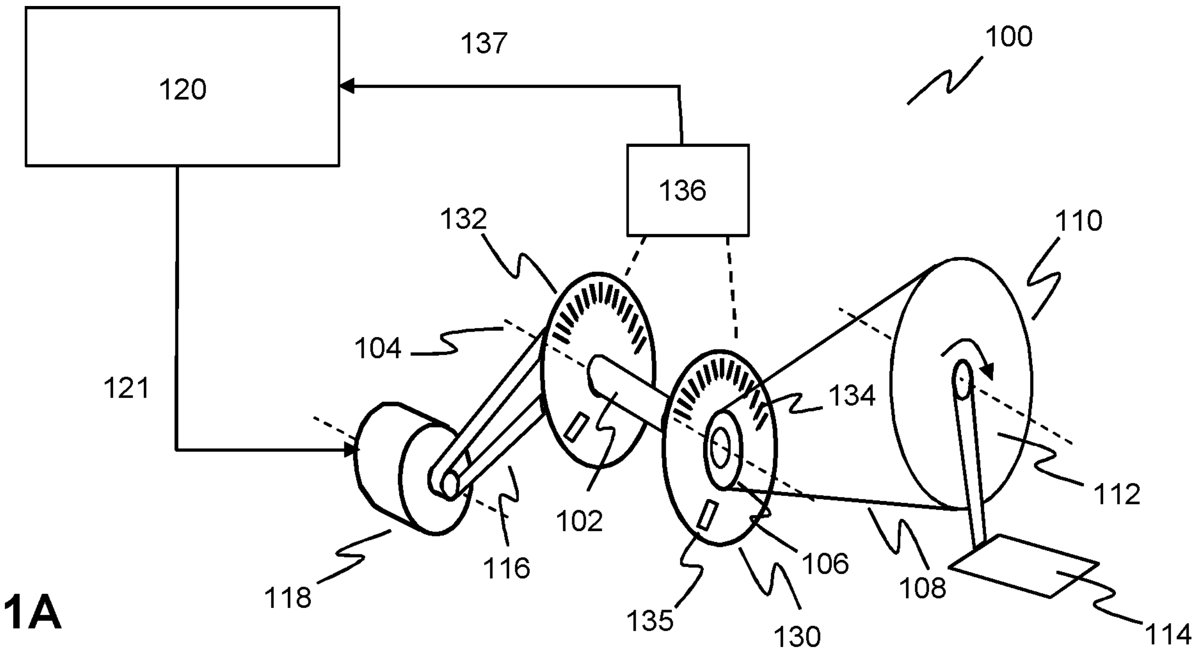


FIG. 1A

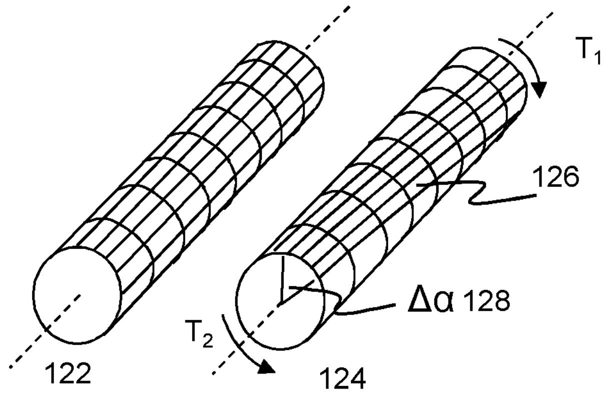


FIG. 1B

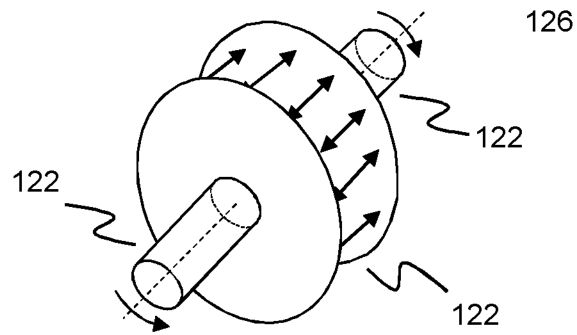


FIG. 1C

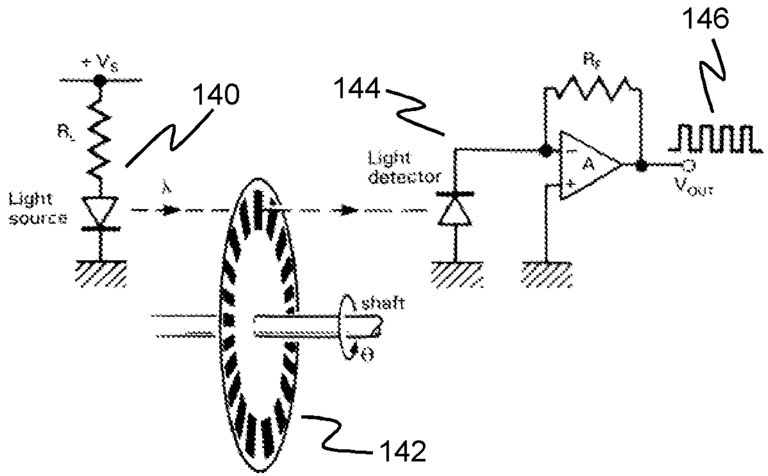
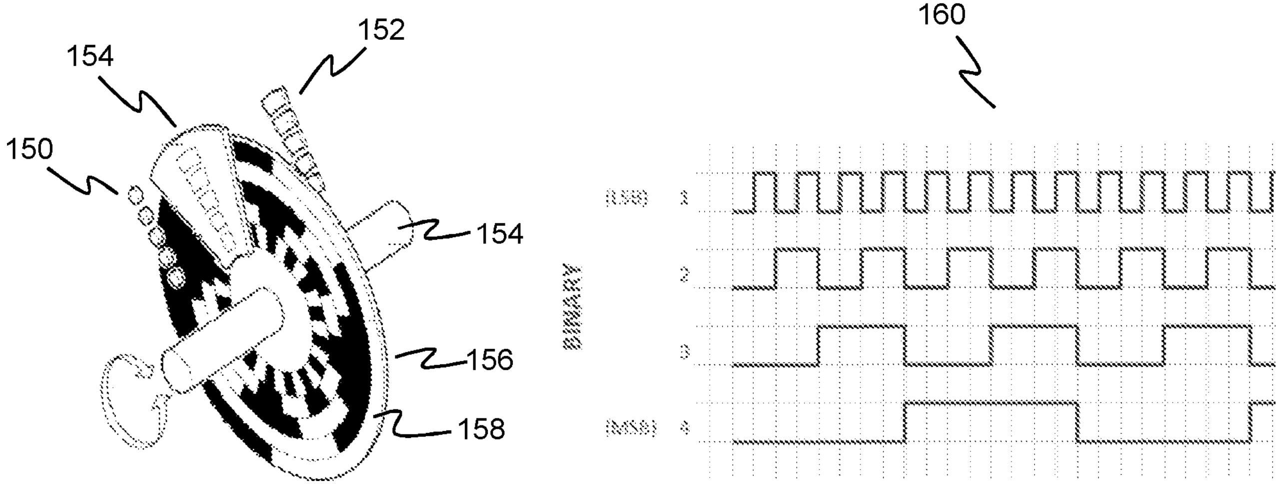


FIG. 1D



Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001
10	1010

FIG. 1E

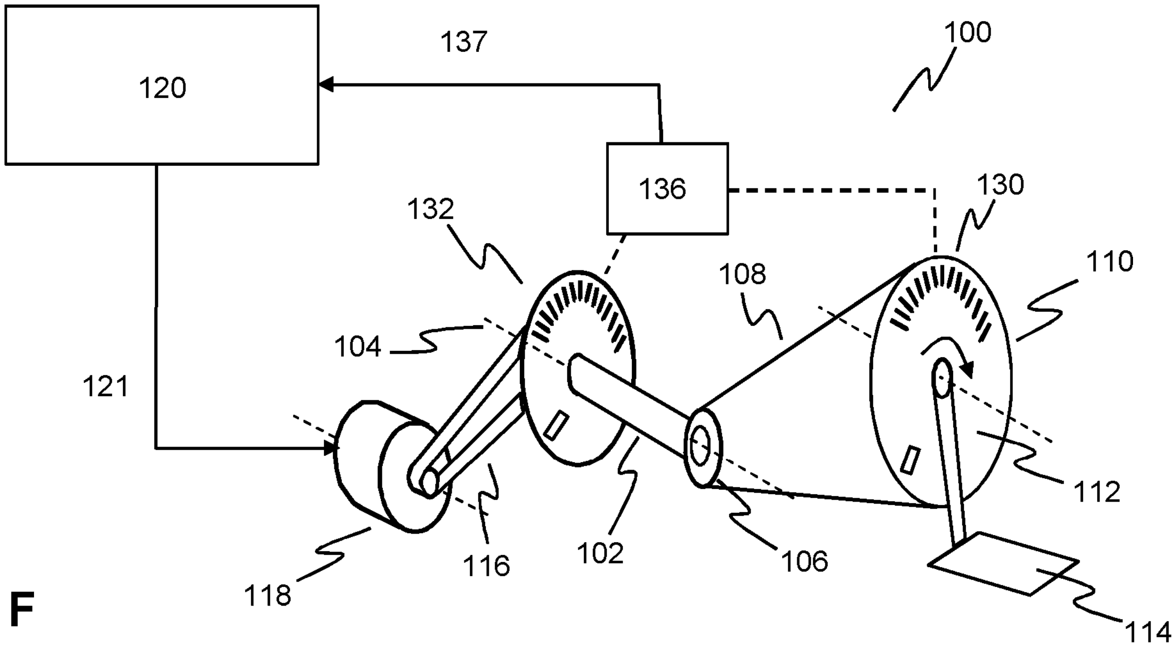


FIG. 1F

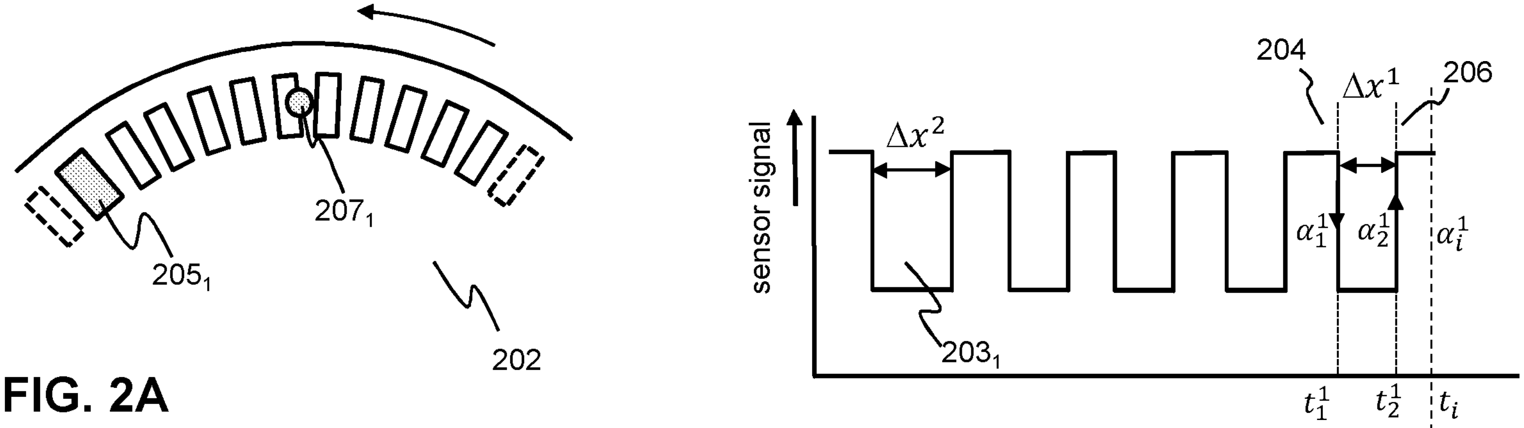

207$_1$
205$_1$
202
sensor signal
Δx^2
204
Δx^1
206
α_1^1
α_2^1
α_i^1
203$_1$
t_1^1
t_2^1
t_i

FIG. 2A

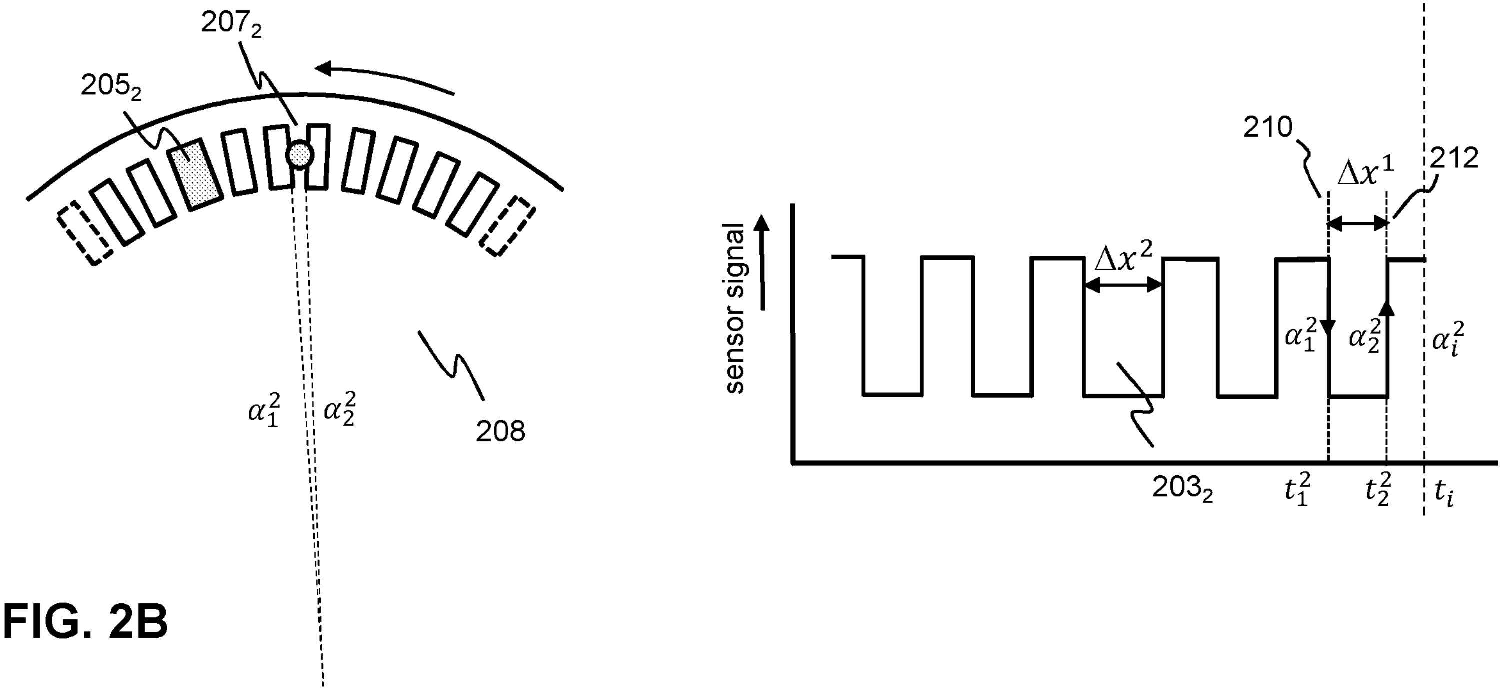

207$_2$
205$_2$
α_1^2
α_2^2
208
sensor signal
210
Δx^1
212
Δx^2
α_1^2
α_2^2
α_i^2
203$_2$
t_1^2
t_2^2
t_i

FIG. 2B

a processor receiving at least one signal from an encoder system, the encoder system being configured to measure first absolute position information of a first part of a rotatable shaft and second absolute position information of a second part of the rotatable shaft, the signal being generated by the encoder system in response to a first torque exerted to the first part of the rotatable shaft

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the processor using the first and second absolute position information in the at least one signal to compute an angle of twist between the first part and second part of the shaft; and using the angle of twist to compute a control signal for a force feedback system, the force feedback system including a force generating device connected to the second part of the rotational shaft

304

the processor transmitting the control signal to the force generating device, the control signal instructing the force generating device to exert a second torque to the second end of the shaft, the second torque being opposite to the first torque.

306

FIG. 3

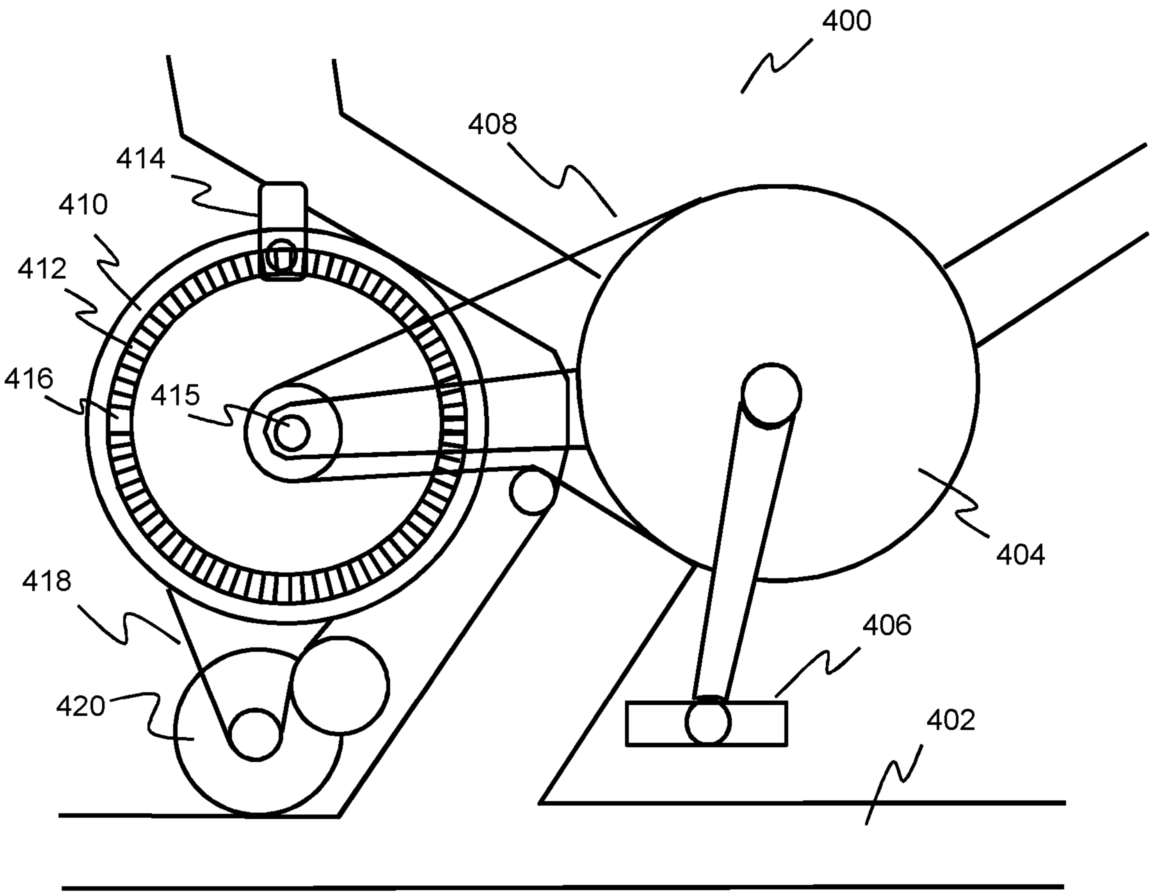
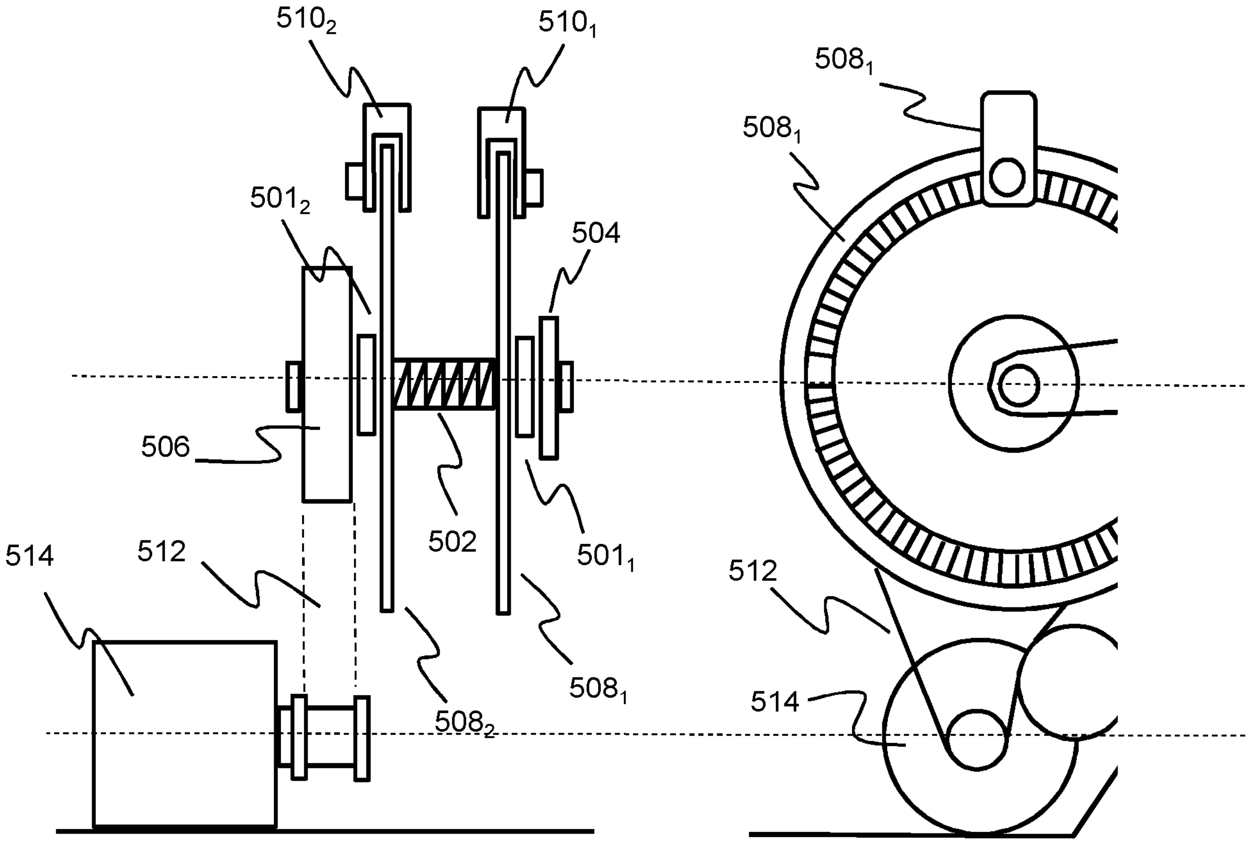
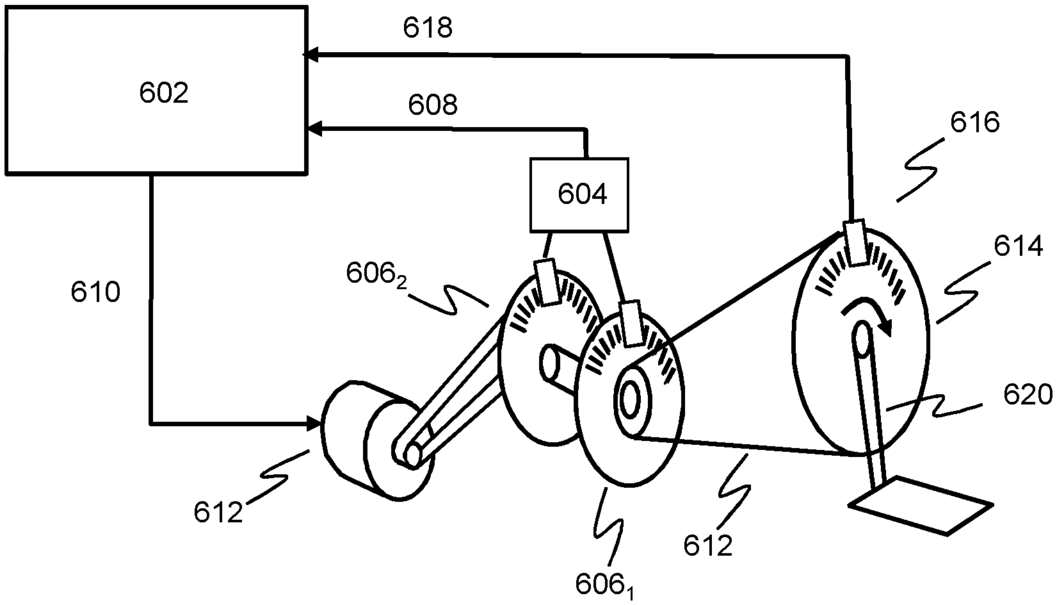


FIG. 4



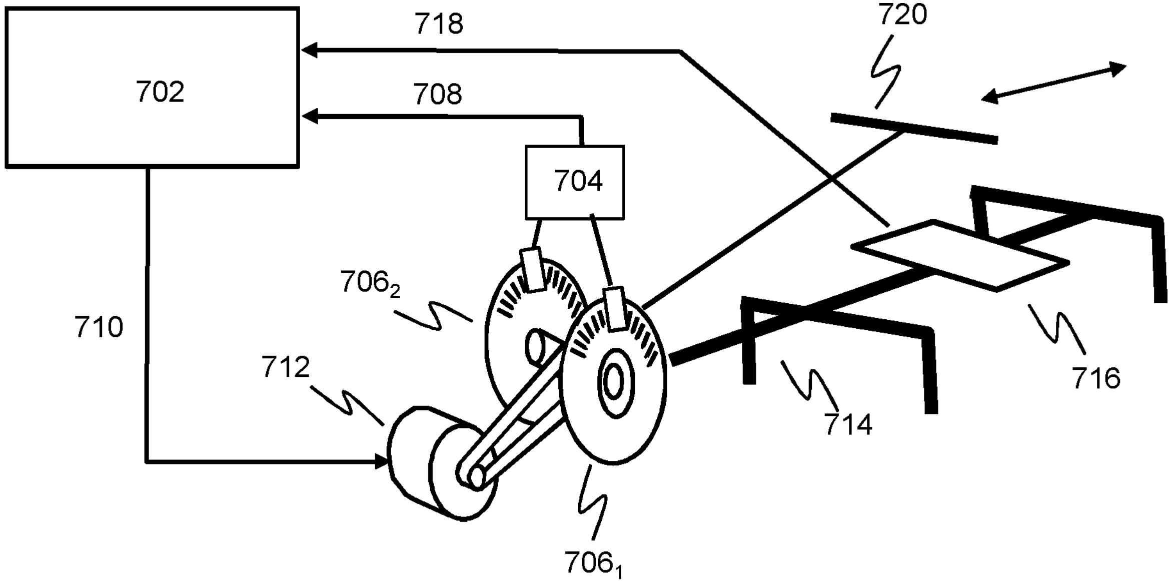
510₂
510₁
508₁
508₁
501₂
504
506
502
501₁
514
512
512
508₂
508₁
514

FIG. 5



602
618
608
604
616
614
6062
610
620
612
612
6061

FIG. 6



702
718
708
720
704
7062
710
712
716
714
7061

FIG. 7

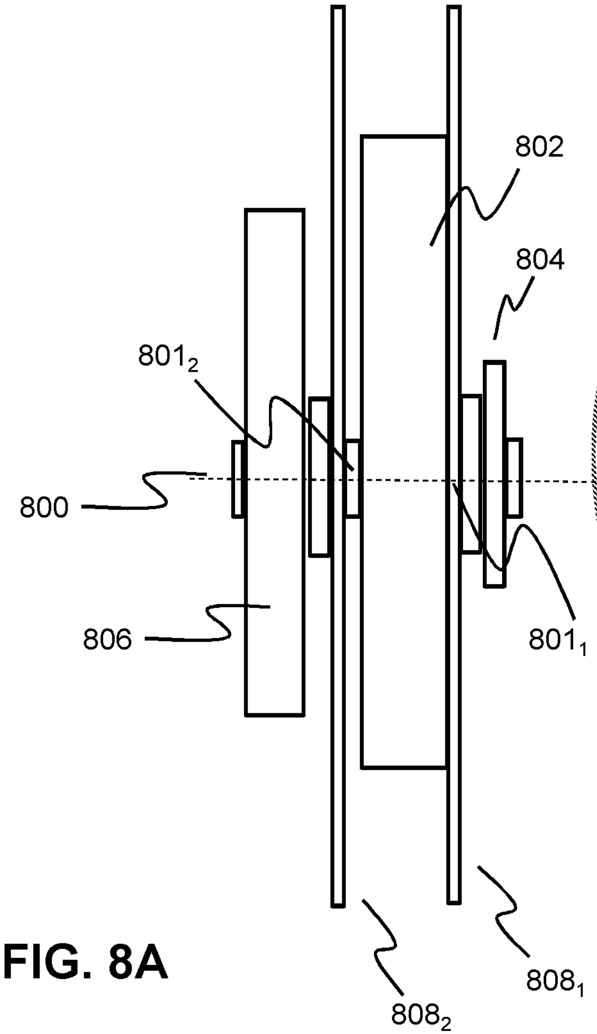


FIG. 8A

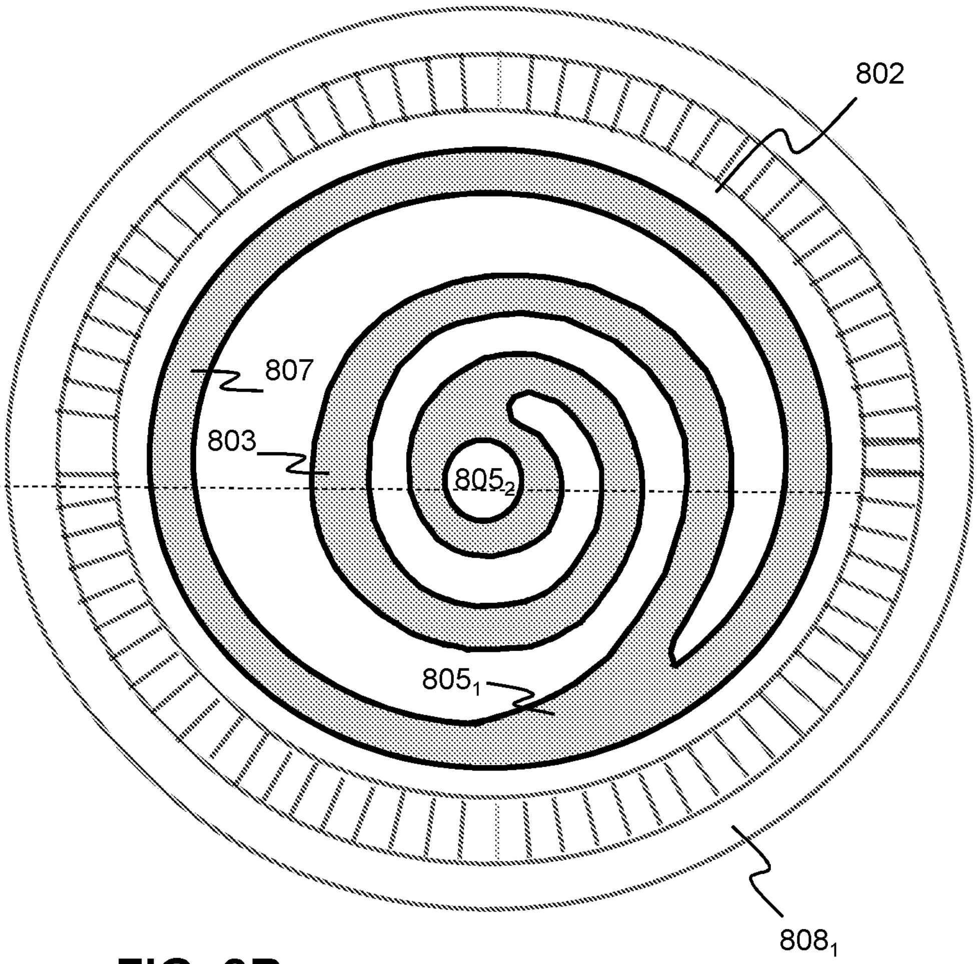


FIG. 8B

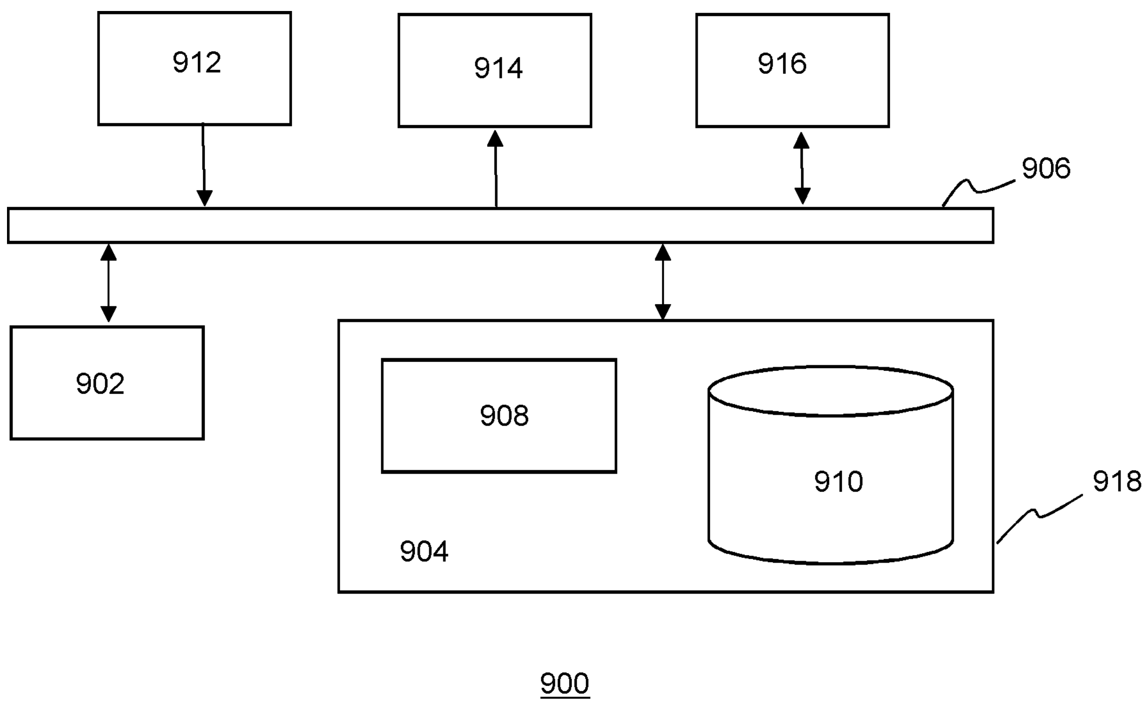


FIG. 9

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	**KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE** **NL28394-Vi/Lb**
Nederlands aanvraag nr. **2021908**	Indieningsdatum **31-10-2018**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **TrueKinetix B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **23-02-2019**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN72997**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)
Volgens de internationale classificatie (IPC) **G01L3/10**
II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC	**G01L;A63B**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	X	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2021908

A. CLASSIFICATIE VAN HET ONDERWERP
INV. G01L3/10
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
G01L A63B

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
	EENHEID VAN UITVINDING ONTBREEKT zie aanvullingsblad B -----	
X	US 2009/211376 A1 (LANDRIEVE FRANCK [FR]) 27 augustus 2009 (2009-08-27) * het gehele document * -----	1,3,5,6, 8
X	US 2002/050178 A1 (DESBIOLLES PASCAL [FR]) 2 mei 2002 (2002-05-02) * alineas [0001] - [0005], [0022] - alinea [0033]; conclusies 1,6; figuren 1-3 * -----	1-9
X	US 2016/116353 A1 (HULSE AARON [US] ET AL) 28 april 2016 (2016-04-28) * het gehele document * -----	1-9
	-/--	

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

18 juni 2019

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie
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De bevoegde ambtenaar

Molina Encabo, Aitor

1

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A	US 5 845 727 A (MIYAZAWA HIROSHI [JP] ET AL) 8 december 1998 (1998-12-08) * column 9, line 17 to column 10, line 64; conclusies 1,17-20; figuren 7,8 * -----	1-8
A	WO 2011/047397 A2 (ANTON PAAR GMBH [AT]; RAFFER GERHARD [AT]) 28 april 2011 (2011-04-28) * page 2, lines 13 - 17; figuren 1-6 * -----	1-8
A	US 4 630 033 A (BAKER ALAN J [US]) 16 december 1986 (1986-12-16) * figuren 1-15B * -----	1-8
A	DE 196 21 185 A1 (NORDMANN KLAUS DR ING [DE]) 4 december 1997 (1997-12-04) * het gehele document * -----	1-9
A	EP 2 579 011 A2 (YAO LI HO [TW]) 10 april 2013 (2013-04-10) * het gehele document * -----	1-9

1

GEBREK AAN EENHEID VAN UITVINDING

Octrooiaanvrage Nr.:

SN 72997
NL 2021908

AANVULLINGSBLAD B

De Instantie belast met het uitvoeren van het onderzoek naar de stand van de techniek heeft vastgesteld dat deze aanvrage meerdere uitvindingen bevat, te weten:

1. conclusies: 1-8(compleet); 9(gedeeltelijk)

    Torque sensor with increased accuracy

    ---

2. conclusies: 10-13, 15, 16(compleet); 9(gedeeltelijk)

    Dynamically resistive human training apparatus

    ---

3. conclusie: 14

    Spiral spring torque sensor constructional details

Het vooronderzoek werd tot het eerste onderwerp beperkt.

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek

NL 2021908

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2009211376 A1	27-08-2009	EP 1875184 A2	09-01-2008
		FR 2884918 A1	27-10-2006
		JP 2008538415 A	23-10-2008
		US 2009211376 A1	27-08-2009
		WO 2006111667 A2	26-10-2006
US 2002050178 A1	02-05-2002	EP 1202035 A1	02-05-2002
		FR 2816051 A1	03-05-2002
		JP 2002195897 A	10-07-2002
		US 2002050178 A1	02-05-2002
US 2016116353 A1	28-04-2016	EP 3204745 A1	16-08-2017
		US 2016102724 A1	14-04-2016
		US 2016116353 A1	28-04-2016
US 5845727 A	08-12-1998	CN 1153499 A	02-07-1997
		JP H092368 A	07-01-1997
		JP 3417147 B2	16-06-2003
		TW 320614 B	21-11-1997
		US 5845727 A	08-12-1998
		WO 9700193 A1	03-01-1997
WO 2011047397 A2	28-04-2011	AT 508705 A1	15-03-2011
		CN 102713561 A	03-10-2012
		DE 112010004108 A5	25-10-2012
		GB 2486865 A	27-06-2012
		US 2012210774 A1	23-08-2012
		WO 2011047397 A2	28-04-2011
US 4630033 A	16-12-1986	GEEN	
DE 19621185 A1	04-12-1997	GEEN	
EP 2579011 A2	10-04-2013	EP 2579011 A2	10-04-2013
		KR 20130038119 A	17-04-2013
		TW 201224419 A	16-06-2012
		US 2013086995 A1	11-04-2013

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN72997	31.10.2018		NL2021908

International Patent Classification (IPC)
INV. G01L3/10

Applicant
TrueKinetix B.V.

This opinion contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☒ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☒ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☒ Box No. VII — Certain defects in the application
- ☐ Box No. VIII — Certain observations on the application

Examiner
Molina Encabo, Aitor

Application number

WRITTEN OPINION

NL2021908

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Application number

WRITTEN OPINION

NL2021908

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step, or to be industrially applicable have not been examined in respect of

☐ the entire application

☒ claims Nos. 10-16(compleet); 9(gedeeltelijk)

because:

☐ the said application, or the said claims Nos. relate to the following subject matter which does not require a search *(specify)*:

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no search report has been established for the whole application or for said claims Nos. 10-16(compleet); 9(gedeeltelijk)

☐ a meaningful opinion could not be formed as the sequence listing was either not available, or was not furnished in the international format (WIPO ST25).

☐ a meaningful opinion could not be formed without the tables related to the sequence listings; or such tables were not available in electronic form.

☐ See Supplemental Box for further details.

Box No. IV Lack of unity of invention

1. The requirement of unity of invention is not complied with for the following reasons:

   see separate sheet

2. This report has been established in respect of the following parts of the application:

   ☐ all parts.

   ☒ the parts relating to claims Nos. (see Search Report)

WRITTEN OPINION

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	
	No:	Claims	1-8(compleet); 9(gedeeltelijk)
Inventive step	Yes:	Claims	
	No:	Claims	1-8(compleet); 9(gedeeltelijk)
Industrial applicability	Yes:	Claims	1-8(compleet); 9(gedeeltelijk)
	No:	Claims	

2. Citations and explanations

see separate sheet

Box No. VII Certain defects in the application

see separate sheet

1 **<u>Re Item IV</u>**

Lack of unity of invention

1.1 1. Conclusies: 1-8(compleet); 9(gedeeltelijk)

Torque sensor with increased accuracy

2. Conclusies: 10-13, 15, 16(compleet); 9(gedeeltelijk)

Dynamically resistive human training apparatus

3. Conclusie: 14

Spiral spring torque sensor constructional details

1.2 For the purpose of this non-unity reasoning reference is made to the following document:

D1 US 2009/211376 A1 (LANDRIEVE FRANCK [FR]) 27 augustus 2009 (2009-08-27)

1.3 The reasons for which the inventions are not so linked as to form a single general inventive concept, are as follows:

1.3.1 The common matter linking together independent claims 1 (device), 10 (computer controlled device), 14 (device) and 15 (method) is an elastic torque sensor with two angular absolute position indicators and/or a human training device.

1.3.2 The common matter of an elastic torque sensor with two angular absolute position indicators does not comprise a single general inventive concept, based on same or corresponding underlying problems/special technical features, because it is well known in the art as disclosed by D1.

1.3.3 The common matter of a human training device does not comprise a single general inventive concept, based on same or corresponding underlying problems/special technical features, because it is well known in the art by the person skilled in the art of human training devices.

1.4 <u>Prior art, D1, discloses the following features of claim 1:</u>

1.4.1 D1 (Fig. 1 - 9) discloses, *een draaimoment-meetsysteem* (claim 1)*, omvattend:*
een draaibare schacht (2) *met een eerste deel* (connected to the steering wheel) *en een tweede deel* (connected to the steering rack)*, welke schacht* (2) *een veerstructuur* (3) *omvat tussen het eerste en tweede deel* (Fig. 1)*;*
een eerste uitleesstructuur (22) *verbonden met het eerste deel* (Fig. 1) *die eerste positie-indicatoren omvat* (Fig. 2 and 5) *en een tweede uitleesstructuur (23) verbonden met het tweede deel die tweede positie-indicatoren omvat* (see paragraphs [0047] - [0050] and Fig. 6)*;*
een encodeersysteem ingericht om een eerste absolute draaipositie van het eerste deel van de schacht (2) *te meten gebaseerd op de eerste positie-indicatoren* (22, see claims 6 and 7) *en een tweede absolute draaipositie gebaseerd op de tweede positie-indicatoren* (23, see claims 6 and 7)*;*
waarin in reactie op een externe kracht op het eerste en/of tweede deel, het verschil tussen een eerste en tweede absolute draaipositie, gemeten door het encodeersysteem, een verdraaiingshoek bepaalt (claim 1 and paragraphs [0064] - [0071], this is how all elastic torque sensors work)*.*

1.4.2 D1 **also** discloses the features of claims 3, 5, 6, 7, and 8.

1.5 Prior art, D1, discloses the following features of claim 10:

1.5.1 D1 (Fig. 1 - 9) discloses, ~~*een computergestuurd trainingstoestel omvattend:*~~ *een frame* (the vehicle)*; een draaibaar op het frame bevestigde schacht* (2)*; ten minste één krachtontvangende structuur* (the steering wheel) *die draaibaar verbonden is met een eerste deel van de draaibare schacht* (2)*; en, een krachtopwekkend apparaat* (14) *verbonden met het tweede deel van de draaibare schacht* (indirectly, the claim does not specify a direct connection)*;*
een encodeersysteem ingericht om eerste absolute positie-informatie te meten van het eerste deel van de draaibare schacht en tweede absolute positie-informatie te meten van het tweede deel van de draaibare schacht (claims 1, 6, and 7 and paragraphs [0047] - [0050])*, waarbij de eerste en tweede positie-informatie gegenereerd wordt door het encodeersysteem* (claims 1, 6, and 7) *in reactie op het door een gebruiker van het ~~trainings~~toestel uitoefenen van een kracht op de krachtontvangende structuur* (steering wheel)*, welke kracht een eerste draaimoment uitoefent op het eerste deel van de draaibare schacht* (2)*; en,*
een kracht-terugkoppelsysteem die een computergestuurd krachtopwekkend apparaat bevat dat draaibaar verbonden is met het tweede deel van de schacht (the steering assist motor 14)*, en een processor van een computer*

ingericht om een verdraaiingshoek te bepalen tussen het eerste en tweede deel van de schacht op basis van de eerste en tweede absolute positie-informatie (claim 1 and paragraphs [0064] - [0071]) *en om het krachtopwekkend apparaat aan te sturen om een tweede draaimoment uit te oefenen op het tweede deel van de schacht, gebaseerd op de eerste en tweede draaimoment* (steering assistance is proportional to the senses torque)*, ~~welk tweede draaimoment tegengesteld is aan het eerste draaimoment.~~*

1.6 Prior art, D1, discloses the following features of claim 14:

1.6.1 D1 (Fig. 1 - 9) discloses, *een ~~torsie~~veerstructuur voor een draaimoment-meetsysteem* (claim 1) *~~van een trainingstoestel~~, welke ~~torsie~~veerstructuur een draaibare schacht* (2) *omvat en een koppelstructuur* (3) *die een eerste deel van de schacht* (2) *verbindt met een tweede deel van de schacht* (2)*, welke koppelstructuur* (3) *één of meer ~~(spiraal) draaitorsieveerstructuren, drukveerstructuren en/of (visco)~~elastische veerstructuren omvat* (3 is a type of spring)*, waarbij de ~~torsie~~veerstructuur bij voorkeur vervat is in een ronde omhulling , ~~waarbij de torsieveer een buitenste uiteinde bevat verbonden met de buitenste omhulling, welke buitenste omhulling verbonden is met het eerste deel van de schacht en de torsieveer een binnenste uiteinde bevat verbonden met het tweede deel van de schacht.~~*

1.7 Prior art, D1, discloses the following features of claim 15:

1.7.1 D1 (Fig. 1 - 9) discloses, *een werkwijze ~~voor het aansturen van een kracht-terugkoppelsysteem van een trainingstoestel~~ omvattend:*
het door een processor ontvangen van ten minste één signaal van een encodeersysteem (claims 1, 6, and 7 and paragraphs [0047] - [0050])*, welk encodeersysteem ingericht is om eerste absolute-positie-informatie te meten van een eerste deel van een draaibare schacht* (2) *en tweede absolute-positie-informatie van een tweede deel van de draaibare schacht* (2, see claim 6 and 7) *~~van een trainingstoestel~~, waarbij het signaal genereerd wordt door het encodeersysteem in reactie op een externe kracht, e.g. een gebruiker ~~van het trainingstoestel~~ die ten minste een eerste draaimoment uitoefent op het eerste deel van de draaibare schacht* (claim 1 and it the user inputs thier force via the steering wheel)*;*
het door de processor gebruiken van eerste positie-informatie en tweede positie-informatie in het ten minste één encodeersignaal om een

verdraaiingshoek te berekenen tussen het eerste deel en het tweede deel van de schacht (claim 1 and paragraphs [0064] - [0071])*; en, het gebruiken van de verdraaiingshoek om een regelsignaal te berekenen voor het kracht-terugkoppelsysteem* (Paragraphs [0064] - [0071])*, welk kracht-terugkoppelsysteem een krachtopwekkend apparaat* (14) *bevat dat draaibaar verbonden is met het tweede deel van de draaibare schacht* (2, see Fig. 1)*; en,*
het door de processor verzenden van het regelsignaal naar het krachtopwekkend apparaat (14, and Fig 4 and 8)*, welk regelsignaal het krachtopwekkend apparaat* (14) *instrueert om een tweede draaimoment uit te oefenen op het tweede deel van de schacht* (the steering assist torque, paragraphs [0068] and [0069]), ~~*welk tweede draaimoment tegengesteld is aan het eerste draaimoment.*~~

Hence, the following separate inventions or groups of inventions are not so linked as to form a single general inventive concept:

1.8 **Group/Invention 1:** Claims 1 - 8 and claim 9 in combination with any one of the claims 2 and 4.

1.8.1 The following features of claims 2 and 4 are not known from the prior art of D1:

- *waarin de veerstructuur ingericht is om een maximum verdraaiingshoek te verschaffen die groter dan de draaihoek tussen twee opeenvolgende positie-indicatoren van de eerste en tweede uitleesstructuur.*

- *waarin de veerstructuur een torsieveer omvat, bij voorkeur een spiraal-torsieveer.*

1.8.2 Underlying Problem 1: How to increase the accuracy and measurment magnitude of a torque sensor.

1.8.3 Special Technical Feature 1: Details of a torque sensor which allow the torque sensor to deflect more than normal and for this increased deflection to be accuratly measured.

1.9 **Group/Invention 2:** Claim 9 in combination with any one of the claims 1, 3, and 5 - 8, and claims 10 - 13 and 15 and 16.

1.9.1 The following features of the above claims are not known from the prior art of D1:

- *een computergestuurd trainingstoestel omvattend:*

- *welk tweede draaimoment tegengesteld is aan het eerste draaimoment.*

1.9.2 Underlying Problem 2: How to train a human by providing a counter torque proportional to their human effort.

1.9.3 Special Technical Feature 2: Details of a human training device providing a resistive torque to the human effort.

1.10 **Group/Invention 3:** Claim 14

1.10.1 The following features of claim 14 are not known from the prior art of D1:

- *waarbij de torsieveer een buitenste uiteinde bevat verbonden met de buitenste omhulling, welke buitenste omhulling verbonden is met het eerste deel van de schacht en de torsieveer een binnenste uiteinde bevat verbonden met het tweede deel van de schacht.*

1.10.2 Underlying Problem 3: How to build/implement a spiral spring torque sensor.

1.10.3 Special Technical Feature : Constructional details of a spiral spring torque sensor.

1.11 **Reasoning:**

1.11.1 A common concept shared by the above Groups/Inventions 1 - 4 could be defined as, improving a torque sensor or human training device, however in retrospect this concept is not new with respect to the known prior art D1 or the skilled person's general knowledge, and thus not inventive.

1.11.2 The above analysis shows that the Special Technical Features of the various groups/inventions are not the same. Furthermore these collection of features do not have any relationship with each other due to the following reasons: a comparison of the underlying problems, as viewed in the light of the description and drawings, shows that the problems to be solved by the various groups/inventions are different and have no common/shared technical effect, so that the special technical features must be seen to not correspond.

1.11.3 Hence neither the objectively determined underlying problems, nor the solutions provided for them via the Special Technical Features, provide a basis for establishing a relationship between the named groups/inventions.

1.11.4 Therefore the named groups/inventions cannot be seen to correspond/ correlate to an extent that they share a common inventive idea. The application does not fulfill the requirements of unity of the invention.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Claims 1 - 8 and claim 9 when dependent on either claim 2 or 4.

Reference is made to the following documents:

D1 US 2009/211376 A1 (LANDRIEVE FRANCK [FR]) 27 augustus 2009 (2009-08-27)

D2 US 2002/050178 A1 (DESBIOLLES PASCAL [FR]) 2 mei 2002 (2002-05-02)

D3 US 2016/116353 A1 (HULSE AARON [US] ET AL) 28 april 2016 (2016-04-28)

D4 US 5 845 727 A (MIYAZAWA HIROSHI [JP] ET AL) 8 december 1998 (1998-12-08)

D5 WO 2011/047397 A2 (ANTON PAAR GMBH [AT]; RAFFER GERHARD [AT]) 28 april 2011 (2011-04-28)

2 The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.

2.1 D2 discloses, *een draaimoment-meetsysteem* (Claim 1)*, omvattend:* *een draaibare schacht* (1) *met een eerste deel en een tweede deel* (left and right sides)*, welke schacht een veerstructuur omvat* (2) *tussen het eerste en tweede deel* (Fig. 2)*;*

een eerste uitleesstructuur (11-13, links) *verbonden met het eerste deel die eerste positie-indicatoren omvat* (11 links) *en een tweede uitleesstructuur* (11-13 rechts) *verbonden met het tweede deel die tweede positie-indicatoren omvat* (11 rechts)*;*
een encodeersysteem (11 - 13, and paragraph [0022] - [0033]) *ingericht om een eerste absolute draaipositie van het eerste deel van de schacht* (1) *te meten gebaseerd op de eerste positie-indicatoren* (11 links, see paragraphs [0024] - [0027] which discuss measuring the absolute position of the rings 11) *en een tweede absolute draaipositie gebaseerd op de tweede positie-indicatoren* (11 rechts, paragraph [0027], last sentence)*;*
waarin in reactie op een externe kracht op het eerste en/of tweede deel, het verschil tussen een eerste en tweede absolute draaipositie, gemeten door het encodeersysteem, een verdraaiingshoek bepaalt (paragraph [0027], last sentence and claims 1 and 6).

2.2 D1 also discloses the features of claim 1 as stated above.

2.3 D3 (Fig. 1 - 5 and paragraphs [0016] and [0060]) also discloses the features of claim 1.

2.4 The subject-matter of claim 1 is not new in light of what is known from documents D1 - D3. The subject-matter of claim 1 is not inventive in light of what is known from documents D1 - D3.

3 **Claims 2 - 8 and claim 9 when dependent on either claim 2 or 4.**

3.1 The additional features of claim 2 are known from D2 (paragraphs [0022] - [0024]) or D3 are merely a minor constructional variant that a person skilled in the art would implement without the need for an inventive step. The more position indicators measured for a given deformation the higher the torque measuring accuracy will be, the skilled person knows this and would implement the features of claim 2 if more precision is required.

3.2 The additional features of claim 3 are known from D1 - D3. Claim 3 does not state that the torque sensor must be capable of deforming from -20/-10 degrees to 20/10 degrees but that it must deform within that range. D2 has small deformations and therefore falls within the range of claim 3 thereby disclosing the features of claim 3. Additionally torque sensors using two rotary position encoders and having large deformations are well known in the prior art, see D3 (Fig. 7 and 8 and claim 20 and column 9, line 17 to column 10, line 64).

3.3 The additional features of claim 4 are known from D3 (Fig. 1 - 5). The additional features of claim 4 are merely a constructional variant of what is disclosed in D1 or D2 that a person skilled in the art would not hesitate to implement without the need for an inventive step starting from the prior art of D2. See D4 (Fig. 7 and 8 and claims 1 and 17 - 20 and column 9, line 17 to column 10, line 64) which discloses a torque sensor ("leg power" is equivalent to torque) using a "torsieveer" and a similar construction and measurement method to D2. Also see D5 (Fig. 1 - 6 and page 2, lines 13 - 17) torque sensors using "spiraal-torsieveeren" and relative rotation differences are also known from the prior art. Using a spring as discloses in D4 or D5 in D2 would not be considered inventive and is solely dependent on the intended use of the torque sensor. The skilled person would add the absolute position measurement of D1 or D2 to any of these torque sensor without the need for an inventive step if so required (or swap the elastic elements).

3.4 The additional features of claim 5 are known from D1 or D2 (paragraphs [0022] - [0027] and [0033]) or D3 (paragraphs [0059] - [0069]).

3.5 The additional features of claim 6 are known from D1 or D2 (paragraphs [0022] - [0027] and [0033]) or D3 (paragraphs [0059] - [0069]) or are merely a minor constructional variant that a person skilled in the art would implement without the need for an inventive step. The control system must relate each angle value to some kind of identifier in order to differentiate the different angles from each other. D2 discloses that all measured angles may be absolute or relative.

3.6 The additional features of claim 7 are known from D1 or D2 (paragraphs [0022] - [0024] and Fig. 1 - 3) or D3 (paragraphs [0059] - [0069]).

3.7 The additional features of claim 8 are known from D1 or D2 (paragraphs [0022] - [0033] and Fig. 1 - 3) or D3 (paragraphs [0059] - [0069]).

3.8 The additional features of claim 9 are known from D2 (paragraphs [0022] - [0033] and Fig. 1 - 3 and paragraphs [0003] and [0004]). All torque sensors which use a deformable elastic element with angular position sensors on either side of the elastic element use the "verdraaiingshoek" to calculate the torque applied to the torque sensor, D2 naturally does this too. Claim 9 does not define the type of "trainingstoestel" nor does it contain any features which force it to be a particular type of "trainingstoestel". The last sentence of paragraph [0003] states that the torque sensor of D2 may be used for "simulation and training in automobile driving schools", a driving simulator is a type of "trainingstoestel" and as such D2 also discloses this feature. A simulator provides force feedback as described in paragraph [0004] where it is called the "resisting torque", this resisting torque is naturally opposite and proportional to the users input torque. The force feedback motor and computer are implicit to any driving simulator. For at least these reasons D2 discloses all of the features of claim 9. The additional features of claim 9 are known from D3 (paragraphs [0001] and [0002]).

3.9 The subject-matter of claims 2 - 8 and claim 9 when dependent on either claim 2 or 4 is not new and/or inventive in light of what is known from D1 - D5.

4 **Re Item VII**

Certain defects in the application

4.1 Independent claim 1 is not in the two-part form, which in the present case would be appropriate, with those features known in combination from the prior art being placed in the preamble and the remaining features being included in the characterising part.

4.2 The features of claims 1 - 9 are not provided with reference signs placed in parentheses.

4.3 The relevant background art disclosed in D1 and D2 is not mentioned in the description, nor are these documents identified therein.