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(54) EXERCISE DEVICE, DISTORTION DEVICE, CRANK, METHOD OF OPERATING AN EXERCISE DEVICE, AND USE OF AN EXERCISE DEVICE

(57) Exercise device (2) that is arranged to be provided with a pedal (12). The pedal (12) is arranged, when provided on the exercise device (2), for receiving a force exerted by a user of the exercise device (2) and for being repeatedly moved by the user along a trajectory (14) so that a position of the pedal (12) repeatedly varies along the trajectory (14). The exercise device (2) includes a distortion device that is arranged to mechanically couple to the pedal (12) for generating repeated distortional motion of the pedal (12). The distortion device is arranged to control an intensity and/or direction of the distortional motion dependent on the position of the pedal (12) along the trajectory (14) and/or dependent on the force exerted on the pedal (12) along the trajectory (14), so that also the intensity and/or direction varies along the trajectory (14).

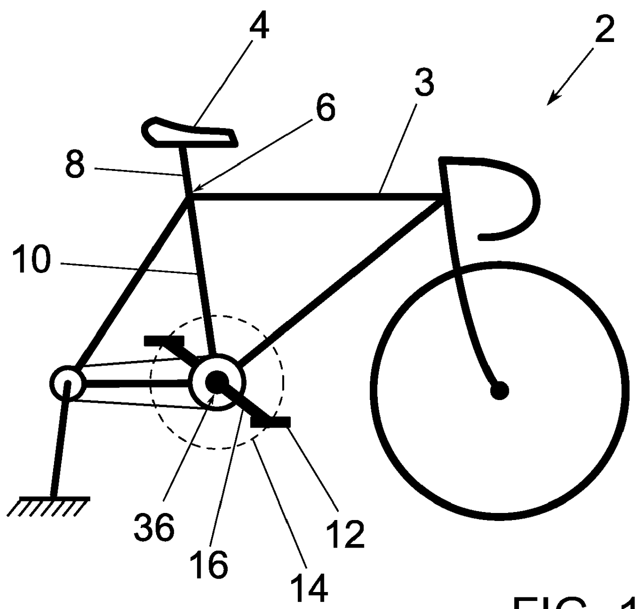

FIG. 1A

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Description

FIELD

[0001] The invention relates to an exercise device. The invention also relates to a distortion device. The invention further relates to a crank. The invention further relates to a method of operating an exercise device. The invention further relates to use of an exercise device.

BACKGROUND

[0002] Osteopenia and osteoporosis affect many women and men worldwide, and can significantly increase vulnerability for suffering fragility bone fractures. The loss of bone density that results in osteopenia or osteoporosis, is most commonly associated with post-menopausal women. However, it also arises in many other demographics, including older-age males and persons with bone disease or other bone disorders. Fragility fractures often reduce quality of life, at least in the short term during medical treatment and further care. Moreover, there is also the possibility of a reduction in quality of life in the longer term, for example due to reduced mobility of a person that has suffered a fracture and due to necessary lifestyle changes.

[0003] Fractures of fragile bone can cause not only a negative change in the quality of life of persons suffering a fracture and of their families, but also forms an economic burden on the healthcare system. The medical treatment and care associated with fractures lead to significant economic costs. Moreover, women and men suffering a fracture often cannot work for a significant amount of time and are also otherwise hindered in participating in the economic process. With the aging population and rising retirement age, the risk of fragility fractures is set to become even more a burden on society.

[0004] Bone science has developed to discover mechanisms behind loss of bone density and measures against it. According to Wolff's law, bone in a healthy person or animal will adapt to the loads under which it is placed. In coordination and cooperation, different cell types play a role in the mechano-regulation of bone. The basic bone structure relevant for strength is formed by osteocytes, which is a type of bone cell that is embedded in bone matrix. Osteocytes communicate via an interconnected canalicular network capable of fluid flow and, in combination with cell-connecting processes, can communicate to other bone cells.

[0005] Bone forming cells, called osteoblasts, exist on the bone surface, and can also sense surface micro-strain directly. In combination with biochemical and mechanical signals, tissue deformation and fluid flow are sensed by cells of this type. Such sensed information is communicated between osteoblasts, and in turn influences cell migration, proliferation, and differentiation that results in bone formation activity. Bone-resorbing cells, called osteoclasts, also exist on the surface of the bone. This type of bone cell is responsible for the removal of the bone matrix, allowing for bone resorption and turnover. An imbalance of this bone-formation and resorption activity can result in lower bone density.

[0006] Some people that are at risk of bone fracturing as a result of osteopenia or osteoporosis are prescribed medication in order to prevent bone fragility fractures. For example, bisphosphonate drugs, most commonly alendronate, are prescribed to slow down bone loss by limiting the osteoclast activity that resorbs bone. Bisphosphonate treatments in general were reported to reduce risk of fractures. As another example, treatments can be based on drugs that aim to produce bone, such as Romosozumab.

[0007] However, treatments based on drugs have significant downsides. For example, a diagnosis or clinical risk assessment is needed before drugs are prescribed. Many diagnoses come only after a fracture has occurred. Moreover, prescribed drug treatments may include warnings for bone loss at the jaw and/or for higher risk of heart attacks and strokes. Hence, the drug approach fails to satisfactorily eliminate problems that occur as a result of osteopenia and osteoporosis.

[0008] Lifestyle changes are also suggested to prevent or counteract osteopenia and osteoporosis, and the results thereof. Lifestyle changes for example may include nutritional considerations, daily impactful exercise, and adapting a lifestyle that reduces the risk of falling. However, the effectiveness of nutrition is considered moderate or even inconclusive. For physical activity, weight-bearing exercise such as jumping, running, or weight-training, is recommended. Evidence exists that demonstrates that mechanical forces influence bone shape and structure. Swimming or cycling however are not considered beneficial to bone health, due to their non-weight bearing nature.

[0009] Patients not complying with programs for regular use of exercise devices or weight bearing physical activity, however still forms a problem. People are required to overcome the barrier of spending time and effort especially directed to using the exercise devices or to carry out weight-bearing physical activity. Moreover, like drug treatments, lifestyle adjustments usually are only prescribed when some form of bone disorder is diagnosed. As there often is no direct pain associated with osteopenia and osteoporosis, many osteopenic or osteoporotic persons are not aware they are at higher risk of fractures until a fracture actually occurs.

[0010] Moreover, while fracturing of for example a bone of a person's arm or wrist, or of a rib or collar bone, can already lead to loss of quality of life or to economic costs, fracturing of a bone in a person's lower limbs or pelvis region is especially riskful. Above all, a fracture of for example a bone in an ankle, hip or leg can severely diminish a person's mobility. This may result in long recovery times, joint replacements, and/or loss of independence. Such incidents may even lead to increased mortality rates.

[0011] US 4,570,927 relates to an indoor therapeutic device directed to reversing osteoporosis in human lower limbs. The device is provided with a crank assembly and pedals, which are rotated by means of a motor of the device. The device further includes a control for regulating the magnitude of the vibrations transmitted to the lower limbs. An accelerometer that has to be mounted to a lower limb provides a feed-back signal used by the control. The device keeps the amplitude of the transmitted vibrations in the leg constant based on the feed-back signal. The use of the feed-back system of US 4,570,927 however provides a barrier to exercising. In particular the placement of the accelerometer may be felt by the user as a burden.

[0012] US 2014/0024502 relates to an indoor exercise device with a pedal assembly and cranks. The device includes a vibrating assembly that is mounted on the exercise device, e.g. on the outer surface of a crank or on another position of the exercise device. The vibrating assembly is described to have the effect of increasing bone density, among other effects. The intensity of the vibrations can be tied to factors such as speed of the pedal assembly or the resistance level provided by a flywheel. US 2014/0024502 does not describe that the intensity is adapted in order to improve the effect of the vibrations on bone density.

[0013] US 4,570,927 and US 2014/0024502 illustrate that devices intended to enhance bone strength may be improved, and at least illustrate a need for an alternative. A satisfactory way of preventing and/or counteracting osteopenia and osteoporosis is lacking. As a result, most people even may develop additional fragility fractures after the first fragility fracture has occurred. Thus, there is a need for another possibility of prevention and/or reduction of osteopenia and/or osteoporosis, preferably in a manner that enables reaching a more beneficial effect and/or is more easily accessible.

SUMMARY

[0014] The present disclosure provides an exercise device that is arranged to be provided with a pedal that is arranged, when provided on the exercise device, for receiving a force exerted by a user of the exercise device and for being repeatedly moved by the user along a trajectory so that a position of the pedal repeatedly varies along the trajectory, wherein the exercise device includes a distortion device that is arranged to mechanically couple to the pedal for generating, preferably repeated, distortional motion of the pedal. According to one aspect, the distortion device is arranged to control an intensity and/or direction of the distortional motion dependent on the position of the pedal along the trajectory and/or dependent on the force exerted on the pedal along the trajectory, so that also the intensity and/or direction varies, preferably repeatedly, along the trajectory. According to another aspect, the distortional motion includes one or more distortion events along the trajectory. These aspects may be combined. Alternatively, only one of these aspects may be implemented on the exercise device. Alternatively, the exercise device may be provided without these aspects, in one or more embodiments, and/or with one or more features or further aspects, disclosed herein.

[0015] Said one aspect enables preferencing a relatively large intensity and/or a preferred direction to occur at a pedal position along the trajectory where a relatively large force on the pedal is exerted by the user. This enables strain and/or strain rates in lower limb bones and the pelvis caused by the distortional motion of the pedal that are effective against osteopenia and osteoporosis. As a result of the force exerted by the user, a foot of the user may be in firm contact with the pedal. Thus, a relatively good transfer of the distortional motion to the leg may be achieved. This enables an improved control of magnitude and/or direction of the strain rate in the lower limbs and pelvis region.

[0016] Said other aspect also enables an effective stimulation of bone tissue. Such stimulation is different from the continuous stimulation known from US 4,570,927 and US 2014/0024502. Instead, said other aspect enables focussing the distortional motion in one or more burst along the trajectory. The distortion events, e.g. bursts, may be alternated by periods with less or no distortional motion. The combination of said one aspect and said other aspect may enable a concentration of the distortional motion in one or more distortion events, within a time period wherein a relatively large force on the pedal is exerted by the user. Preferably, the exercise device is arranged for improving a bone strength of a user of the exercise device. Preferably, the distortion device is arranged to control the distortional motion to improve a bone strength of a user of the exercise device.

[0017] In use of the exercise device, the force exerted by the user on the pedal may repeatedly vary along said trajectory. Thus, the variation in the force may e.g. be substantially similar for a plurality of times the pedal moves through the trajectory. The distortion device is arranged to mechanically couple to the pedal, preferably by means of an actuation arm included by the distortion device, for generating distortional motion of the pedal. Such coupling may be achieved by direct mechanical contact between the distortion device and the pedal, and/or via an intermediate structure that is positioned in between the distortion device and the pedal. Such an intermediate structure may be formed, for example, by a pedal mounting part, by a crank to which the pedal may be mounted, or by a part of such pedal mounting part and/or crank. The exercise device preferably includes the pedal mounting part that is arranged for providing the pedal to the exercise device. Preferably, by including the pedal mounting part, the exercise device is arranged to be provided with the pedal. The direction of the distortional motion may e.g. be controlled to vary relative to a crank body of a crank for the exercise device.

[0018] In an embodiment, the exercise device is further arranged to be provided with a user support for supporting a user of the exercise device, wherein the trajectory includes an extending trajectory portion wherein the pedal moves away from the user support and includes a retracting trajectory portion wherein the pedal moves towards the user support, wherein the distortion device is arranged for controlling the intensity of the, preferably repeated, distortional motion so that, during the repeated movement of the pedal along the trajectory, the intensity is larger in the extending trajectory portion than in the retracting trajectory portion.

[0019] The force exerted by the user on the pedal along the trajectory relative to a maximum force along the trajectory, will normally be larger in the extending trajectory portion compared to the retracting trajectory portion. For example, if the exercise device is a bicycle, a relatively high proportion of the leg and hip muscles are in contraction in the extending trajectory portion. Thus, the exercise device enables that, in use, a larger intensity is associated with a larger exerted force. In addition, this embodiment may also reduce the chance of loss of contact between the pedal and the user. The higher force exerted in the extending trajectory portion may reduce a risk of moving a foot of the user relative to the pedal as a result of the distortional motion, such as accidentally sliding the foot over the pedal. The lower intensity in the retracting trajectory portion may reduce a risk of moving the foot relative to or off the pedal.

[0020] In this embodiment, a positive effect may be enhanced as, in the extending trajectory portion, distortional loads may be applied in a preferred direction, e.g. along a long axis of the tibia and/or tailored for loading on the hips. Preferably, in the extending trajectory portion and/or in the retracting trajectory portion, a crank to which the pedal may be mounted, in use, makes an upward or downward angle of at most 90, preferably at most 80 or at most 60, degrees with the horizontal.

[0021] In an embodiment, the distortion device is arranged to control a direction of the distortional motion relative to the crank. The direction may be controlled dependent on the position of the pedal along the trajectory and/or dependent on the force exerted on the pedal along the trajectory, so that the direction varies, preferably repeatedly, along the trajectory. Controlling both the intensity and the direction of the distortional motion, enables a further improvement of a beneficial effect of the distortional motion. In particular, by controlling the direction, the distortional motion may be better adjusted to the orientation of the bones of the lower limbs and pelvis. Such orientation may change along the trajectory.

[0022] In an embodiment, the distortion device is arranged for controlling the intensity of the, preferably repeated, distortional motion so that, during at least a portion of the trajectory, the intensity is proportional to the force exerted by the user on the pedal relative to a maximum of said force during at least a portion of the trajectory. The intensity may e.g. be proportional to the force exerted by the user on the pedal relative to a maximum of said force, during at least a portion of the trajectory. In an embodiment, the distortion device may be arranged for generating the distortional motion when the exerted force is above a force threshold. Thus, preferably, the distortions are only generated when the exerted force exceeds the force threshold.

[0023] In an embodiment, the exercise device includes a rotatable crankshaft and a crank that includes a crank body that is fixed to the crankshaft, wherein the pedal, when provided on the exercise device, is mechanically coupled to the crank to allow rotational motion of at least part of the pedal relative to the crank body. The pedal thus, in an embodiment, is provided on the exercise device to be repeatedly rotated by the user along the trajectory, e.g. be rotated relative to the user support. Preferably, the pedal is one of two pedals included by the exercise device and the crank is one of two cranks included by the exercise device. Preferably, each crank is fixed to the crankshaft at opposite ends of the crankshaft. Preferably, each crank is fixed to the other crank via the crankshaft. Preferably, each crank has a crank body that is fixed to the crank body of the other crank via the crankshaft. In use, each crank body preferably remains substantially static relative to the other crank body. Preferably, each of the two pedals is mounted to one of the cranks.

[0024] In an embodiment, the crank is arranged to allow, when the pedal is provided on the exercise device, preferably is provided to the pedal mounting part, and is mechanically coupled to the crank, translational motion of at least part of the pedal relative to the crank body. In this way, the distortional motion may be generated primarily in the pedal and preferably in the pedal mounting part. Thus, distortional motion in other parts such as another pedal or a frame of the exercise device, may be diminished or may be substantially prevented. Mechanical distortions in a user's head may for example be reduced. Preferably, the pedal mounting part is received and/or included by the crank.

[0025] In an embodiment, the crank body extends in a longitudinal direction of the crank body. Preferably, the crank body has a longitudinal shape. Preferably, a majority of the distortional motion of the pedal relative to the crank body is directed transverse to the longitudinal direction of the crank body. This may enable to substantially align the distortional motion along a longitudinal direction of a tibia of the user. This also enables to generate the distortional motion when the force exerted by the user is relatively large, in particular in the extending trajectory portion. Preferably, the exercise device is provided with cranks having crank bodies whose longitudinal directions are substantially aligned.

[0026] In an embodiment, the crank, preferably the crank body of the crank, is provided with a slot that is arranged to allow and/or constrain the distortional motion of the pedal relative to the crank body. Preferably, the slot enables movement of the pedal relative to the crank body. The crank preferably is arranged to allow translational motion of the pedal relative to the crank body by means of the slot. The slot can e.g. have a longitudinal shape, an arc shape and/or or a diamond shape. By shaping the slot, a direction of the distortional motion relative to the crank body may be controlled, in particular may be constrained. Preferably, the slot is shaped to allow distortional motion of the pedal relative to the crank body in a direction transverse to the longitudinal direction of the crank body. Preferably, corners and/or one or more ends of the slot are rounded to accommodate the pedal mounting part and/or a pedal axle around which a remainder of the pedal can rotate.

[0027] In an embodiment, the distortion device includes an actuation arm that is arranged to mechanically couple to the pedal for generating the distortional motion. Preferably, the actuation arm includes a pivotable coupling and/or is pivotally connected, preferably is pivotally connected to the crank body. The pivotal coupling and/or the pivotal connection may enable realising translational motion in a direction transverse to the longitudinal direction of the crank body. Thus, in an embodiment, the pivoting element and/or the pivotal connection may be arranged to mechanically couple the actuation arm to the pedal in order to realise the distortional motion of the pedal relative to the crank body to be directed transverse to the longitudinal direction of the crank body. The pivotal coupling and/or the pivotal connection may be positioned to realise mechanical leverage to enhance distortional motion characteristics, such as amplitude (or, in other words, maximum displacement) and/or acceleration.

[0028] In an embodiment, the distortion device includes a sensor arranged for generating a sensor signal that is indicative for the position of the pedal along the trajectory and/or for the force exerted on the pedal. Preferably, the distortion device includes an actuator that is arranged to mechanically couple to the pedal for generating the distortional motion, and includes a controller that is communicatively connected to the sensor to receive the sensor signal and is communicatively connected to the actuator for controlling the intensity and/or direction of the distortional motion by means of a control signal, the controller being arranged for generating the control signal based on the sensor signal.

[0029] The combination of sensor, controller and actuator enables an improved control of the distortional motion. The controller may for example be programmed for turning the distortional motion on or off, based on the sensor signal. The trajectory time, e.g. the time needed for one revolution of the pedal, may vary. Basing the control on the sensor signal may enable the distortion device to generate the distortional motion at about the same pedal position along the trajectory. Improved control may be especially useful for an exercise device being a bicycle that is arranged for transporting the user. Bone strength and/or traffic safety may benefit from the improved control.

[0030] Preferably, the actuator is mounted to, in particular on and/or in, the crank so that, in use, the pedal is translated relative to the crank body as a result of the distortional motion of the pedal generated by means of the actuator. Using the actuator for creating the distortional motion by translational motion of the pedal relative to the crank body, may further enable improved control of the distortional motion. For example, it may limit vibrations on other parts of the exercise device, such as in another pedal of the exercise device. Preferably, the actuator is one of two actuators that are mounted to, in particular on and/or in, different ones of the cranks so that, in use, the pedals are translated relative to the crank bodies included by said cranks as a result of the distortional motion of the pedals generated by means of the two actuators.

[0031] In an embodiment, the distortion device is further arranged to control a direction of the distortional motion relative to the crank body dependent on the position of the pedal along the trajectory and/or dependent on the force exerted on the pedal along the trajectory, so that the direction varies, preferably repeatedly, along the trajectory. The actuator may be a unidirectional actuator (or, in other words, a linear actuator) or a multidirectional actuator. A varying direction may e.g. be enabled by an actuator that can perform actuation in multiple directions. Alternatively, or additionally, a varying direction may be enabled by a plurality of actuators, which may e.g. be unidirectional actuators. A varying direction may increase a beneficial effect of the distortional motion, e.g. because it enables stimulating the bone more broadly.

[0032] In an embodiment, the actuator is one of at least two actuators that are arranged to mechanically couple to the pedal for generating the distortional motion. Preferably, the controller is communicatively connected to the at least two actuators and the control signal is arranged for controlling the at least two actuators. Preferably, the at least two actuators are positioned for generating components of the distortional motion of the pedal in different directions that are inclined and/or opposite relative to each other, and preferably are transverse relative to each other. An angle between inclined directions may e.g. be at least 30 degrees and/or at most 90 degrees. Having at least two, e.g. exactly two, actuators arranged for mechanical coupling to one and the same pedal, enables to control and/or vary the direction of the distortional motion along the trajectory. Such control and/or variation of the direction of the distortional motion may be achieved by varying in time the intensity and/or direction of the at least two actuators relative to each other.

[0033] Preferably, at least one, and preferably all, of the at least two actuators is arranged to mechanically couple to the pedal and to allow motion of the pedal caused by another one, and preferably all, of the at least two actuators. Thus, in case of two actuators per pedal, preferably each actuator is arranged to mechanically couple to the pedal and to allow motion of the pedal caused by the other one of the actuators. The allowed motion may however be restricted, e.g. may be restricted to a range of directions.

[0034] Allowing motion of the pedal caused by another one of the at least two actuators, can be realised in various ways. In an embodiment, at least one of the at least two actuators is positioned at a distance from the pedal that enables mechanically coupling to the pedal for moving the pedal in one of the different directions and for allowing, in another one of the different directions, motion of the pedal relative to the the at least one of the at least two actuators. Preferably, the pedal is mechanically coupled to a counteracting element positioned for counteracting the movement in said one of the different directions. In another embodiment, the at least one of the at least two actuators is pivotably coupled to the pedal for moving the pedal in one of the different directions and for allowing, in another one of the different directions, motion of the pedal relative to the at least one of the at least two actuators.

[0035] In an embodiment, the sensor signal is also indicative for a trajectory time needed for the pedal to move along the trajectory, wherein the controller is arranged for controlling the intensity of the distortional motion so that the intensity is below a, preferably predetermined, intensity threshold when the trajectory time is above a, preferably predetermined, upper trajectory time limit and/or is below a, preferably predetermined, lower trajectory time limit. This embodiment may enable preventing, or at least reducing, the intensity of the distortional motion when a frequency of the pedal moving through the trajectory (also referred to herein as cadence) is outside a certain frequency range, preferably for a certain period of time. The upper trajectory time limit preferably is 1.5 seconds, more preferably 1 second. The lower trajectory time limit preferably is 0.5 seconds, more preferably 0.6 seconds.

[0036] In an embodiment, the sensor signal is also indicative for an angular crank velocity needed for the pedal to move along the trajectory, wherein the controller is arranged for controlling the intensity of the distortional motion so that the intensity is below a, preferably predetermined, intensity threshold when the angular crank velocity is above a, preferably predetermined, upper angular velocity limit and/or is below a, preferably predetermined, lower angular velocity limit. This embodiment may enable preventing, or at least reducing, the intensity of the distortional motion when a velocity of the pedal moving through the trajectory is outside a certain angular velocity range, preferably for a certain period of time. The lower angular velocity limit preferably is 280 degrees per second, more preferably 360 degrees per second. The upper angular velocity limit preferably is 720 degrees per second, more preferably 600 degrees per second.

[0037] In an embodiment, the distortion device includes a cam and a cam follower, the cam defining a cam path for the cam follower. Use of a cam and a cam follower may form a robust way of generating the distortional motion. The cam and the cam follower may e.g. be advantageously applied on a stationary exercise device.

[0038] In an embodiment, the cam and the cam follower are mounted so that, in use, at least one of the cam and the cam follower rotates while the pedal moves along the trajectory so that the cam follower repeatedly follows the cam path, wherein the cam path has one or more deviations from a circular shape for causing the distortional motion as a result of the cam follower following said deviations. Preferably, at least one of the cam and the cam follower are resiliently mounted.

[0039] In an embodiment, the distortion device includes a cam and a cam follower, the cam defining a cam path for the cam follower, the cam and the cam follower being mounted so that, in use, at least one of the cam and the cam follower rotates while the pedal moves along the trajectory so that the cam follower repeatedly follows the cam path, wherein the cam path has one or more deviations from a circular shape for causing the distortional motion as a result of the cam follower following said one or more deviations.

[0040] Preferably, the one or more deviations are distributed unevenly along the cam path. For example, each flat planar cross section through and along an axis of rotation of the cam preferably divides the cam path in two unequal cam path portions, e.g. in two portions of unequal length and/or shape.

[0041] In an embodiment, the cam follower is arranged for repeatedly following the cam path, the cam being attached to the crank and/or the crankshaft so that, in use, the cam rotates as a result of the rotation of the crank and/or the crankshaft, and the cam follower being resiliently mounted. Preferably, the cam path has one or more deviations from a circular shape in order to cause the distortional motion as a result of the resiliently mounted cam follower following said deviations.

[0042] In an embodiment, the exercise device includes a frame, the crankshaft being mounted in the frame to allow rotational motion of the crankshaft relative to the user support, wherein the cam follower is resiliently mounted to the frame and the cam is fixedly attached to the crank and/or the crankshaft so that the cam is arranged to mechanically couple to the pedal. Preferably, the frame is arranged to be provided with the user support.

[0043] In an embodiment, the cam follower is resiliently mounted to, in particular on and/or in, the crank and is arranged to mechanically couple to the pedal. Preferably, the cam is rotatably attached to the crank so that, in use, the cam rotates relative to the crank as a result of the rotation of the crank and/or the crankshaft.

[0044] In an embodiment, the one or more distortion events are predetermined, e.g. predetermined by the distortion device, in particular by a controller of the distortion device. For example, the distortion events may be predetermined by software running on the controller. Alternatively, or additionally, the distortion events may be predetermined by the shape of the cam path and/or the position of the resilient mounting of the cam and/or the cam follower.

[0045] In use, various distortion events may be generated. In an embodiment, in a distortion event, a maximum pedal displacement as a result of the distortional motion is at least 3 mm or 4 mm, and/or at most 25 mm. Preferably, the maximum pedal displacement as a result of the distortional motion is at least 4 mm and/or at most 15 mm. In an embodiment, in a distortion event, an absolute value of a maximum pedal acceleration as a result of the distortional motion is at least 15 m/s^2 and/or at most 60 m/s2, preferably at least 20 m/s^2 and/or at most 45 m/s^2. In an embodiment, in a distortion event, an absolute value of a maximum pedal jerk as a result of the distortional motion is at least 400 m/s^3 and/or at most 4000 m/s^3, preferably at least 800 m/s^2 and/or at most 2500 m/s^2. In an embodiment, in a distortion event, a maximum pedal velocity, as a result of the distortional motion, in a direction towards the user support is larger than a maximum pedal velocity, as a result of the distortional motion, in an opposite direction away from the user support. In an embodiment, in a distortion event, a duration of the one or more distortion events is at least 10 ms and/or at most 50 ms, preferably at least 15 ms and/or at most 30 ms. Such embodiments that further define a distortion event may enable effective stimulation of bone tissue. Two or more of the above ranges, for example the range for maximum pedal displacement between 4 and 25 mm and the range for duration between 10 and 50 ms, preferably are combined.

[0046] In an embodiment, a number of distortion events in the extending trajectory portion is larger than a number of distortion events in the retracting trajectory portion. In an embodiment, the number of distortion events along the trajectory is at least one and/or at most ten. In an embodiment, a number of distortion events in the extending trajectory portion is at least one and/or at most three. This enables focussing the distortional motion in a part of the extending trajectory portion where the exerted force is relatively large, while maintaining a beneficial count of the distortion events per unit of time. Preferably, the retracting trajectory portion is free from distortion events.

[0047] In an embodiment, the distortion device is arranged for generating a predetermined number of distortion events, or a, preferably predetermined, maximum number of distortion events, preferably during a predetermined time period, such as a day or a week. Limiting the number of distortion events per time period may be desirable to increase user satisfaction, increase exercising compliance by the user, prevent unnecessary and/or ineffective loading cycles, reduce power consumption by the distortion device, increase safety, and/or increase device life time of the distortion device.

[0048] In an embodiment, the exercise device is a bicycle that is arranged for transporting the user. In this way, the benefits offered by the bicycle against osteoporosis can be achieved during everyday life, wherein the bicycle is used for transportation. In this way, a significant barrier hindering use of the exercise device can be removed. However, the exercise device may also be used beneficially as a stationary exercise device, e.g. used in a gym. This may enables exercising in a controlled environment under well-defined conditions. In an embodiment, the bicycle is provided with the user support, and preferably has a seating that forms the user support. Preferably, the exercise device is provided in assembly with the pedal, preferably with the pedal provided on the exercise device.

[0049] The present disclosure also provides a distortion device arranged for generating, preferably repeated, distortional motion of a pedal for an exercise device. The distortion device preferably includes a sensor arranged for generating a sensor signal that is indicative for a position of a pedal along a trajectory and/or for a force exerted on the pedal. The distortion device preferably includes an actuator and an actuation arm that is arranged to mechanically couple to the pedal for generating the distortional motion. The distortion device preferably includes a controller that is, in use, communicatively connected to the sensor to receive the sensor signal and is, in use, communicatively connected to the actuator for controlling the intensity and/or direction of the distortional motion by means of a control signal, the controller being arranged for generating the control signal based on the sensor signal. Preferably, the distortion device is a distortion device as described herein above in relation to the exercise device.

[0050] The present disclosure also provides a crank that includes a crank body. The crank preferably includes, and/or is arranged to receive, a pedal mounting part that is arranged for mounting a pedal to the crank, the crank being arranged to allow motion of the pedal mounting part relative to the crank body. Preferably, the crank includes a pedal mounting part received by the crank. Preferably, the crank is arranged for receiving an actuator and/or actuation arm. Preferably, the actuator and/or actuation arm is positioned to mechanically couple to the pedal mounting part for generating distortional motion of the pedal and/or the pedal mounting part. Thus, preferably there is provided a crank including a crank body and including, and/or being arranged to receive, a pedal mounting part that is arranged for mounting a pedal to the crank, the crank being arranged to allow motion of the pedal mounting part relative to the crank body, the crank being further arranged for receiving an actuation arm that is positioned to mechanically couple to the pedal mounting part for generating distortional motion of the pedal and the pedal mounting part. Preferably, the crank is a crank as described herein above in relation to the exercise device. Preferably, the crank is provided with the actuation arm and/or the pedal.

[0051] In an embodiment, the crank includes a crank body, wherein the crank body is provided with a cavity for receiving, at least, the pedal mounting part or a part thereof and/or the actuator and/or actuation arm, or a part thereof.

[0052] In an embodiment, the crank is provided in assembly with a distortion device that includes the actuator and/or actuation arm, the distortion device being arranged to mechanically couple to the pedal by means of the actuator and/or actuation arm for generating, preferably repeated, distortional motion of the pedal. Preferably, the distortion device is a distortion device according to the present disclosure. In an embodiment, the assembly includes an actuator according to the present disclosure.

[0053] In an embodiment, the crank is provided in combination with another crank to form a crank set. Preferably, the crank also includes a crankshaft for connecting both cranks of the crank set. The cranks, in particular the crank bodies of the cranks, of the crank set may be similar and/or designed to be mounted at different sides of the bracket of the frame. In use, each crank of the crank set may be fixed to the crankshaft at one of the opposite ends of the crankshaft.

[0054] The present disclosure also provides a method of operating an exercise device. The exercise device may be arranged to be provided with a pedal, and preferably is provided with the pedal, that is arranged to receive a force exerted by a user of the exercise device. The method preferably includes: providing the pedal on the exercise device for allowing repeated movement of the pedal by the user along a trajectory so that a position of the pedal repeatedly varies along the trajectory; generating, by means of a distortion device that mechanically couples to the pedal, preferably repeated, distortional motion of the pedal; and controlling, by means of the distortion device, the intensity and/or direction of the distortional motion dependent on a position of the pedal along the trajectory and/or dependent on the force exerted on the pedal along the trajectory, so that also the intensity and/or direction varies, preferably repeatedly, along the trajectory. The direction of the distortional motion may e.g. be controlled to vary relative to a crank body of a crank for the exercise device.

[0055] The exercise device preferably is further arranged to be provided with a user support for supporting a user of the exercise device. In an embodiment, the method includes: providing the pedal on the exercise device for allowing repeated motion of the pedal relative to the user support along the trajectory, wherein the trajectory includes an extending trajectory portion wherein the pedal moves away from the user support and includes a retracting trajectory portion wherein the pedal moves towards the user support; generating, by means of a distortion device that mechanically couples to the pedal, distortional motion of the pedal; and controlling, by means of the distortion device, the intensity of the distortional motion so that, during the repeated motion of the pedal along the trajectory, the intensity is larger in the extending trajectory portion than in the retracting trajectory portion.

[0056] In an embodiment, the method includes: generating, by means of a sensor included by the distortion device, a sensor signal that is indicative for the force exerted on the pedal and/or is arranged for sensing a position of the pedal along the trajectory; generating, by means of an actuator that is included by the distortion device and mechanically couples to the pedal, the distortional motion; receiving, by means of a controller that is included by the distortion device and is communicatively connected to the sensor, the sensor signal; generating, by means of the controller that is further communicatively connected to the actuator, a control signal that is based on the sensor signal; and controlling the intensity and/or the direction of the distortional motion based on the control signal.

[0057] The present disclosure also provides use of an exercise device and a method of exercising by means of an exercise device, the exercise device being provided with a user support and with a pedal for allowing repeated motion of the pedal relative to the user support along a trajectory. The method and/or use preferably includes, preferably repeatedly: supported on the user support of the exercise device, exercising a force on the pedal of the exercise device; moving the pedal away from the user support in an extending trajectory portion that is included by the trajectory; moving the pedal towards the user support in a retracting trajectory portion that is included by the trajectory; receiving distortional motion of the pedal that is generated by a distortion device that is included by the exercise device and that mechanically couples to the pedal, the intensity of the distortional motion being controlled by the distortion device to be larger in the extending trajectory portion than in the retracting trajectory portion.

[0058] Preferably, in the use and/or in one or more of the methods described herein (i.e., in a method of operating and/or in a method of exercising), the exercise device is a bicycle, the use and/or method including transporting the user by means of the bicycle. In an embodiment of the use and/or in an embodiment of one or more of the methods described herein, the exercise device is an exercise device according to the present disclosure, the exercise device is provided with a distortion device according to the present disclosure, and/or the exercise device is provided with a crank according to the present disclosure.

[0059] In an embodiment of the use and/or one or more of the methods described herein, the use and/or method may include: determining a state of at least one bone of a lower limb and pelvis region of the user; and controlling the distortional motion, in particular the intensity and/or direction of the distortional motion, based on the state of the at least one bone. Preferably, the use and/or method includes verifying a state of the at least one bone and adapting the distortional motion, in particular the intensity and/or direction of the distortional motion, based on the state of the at least one bone. In an embodiment, the use and/or method may include transporting the user of the exercise device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0060] The invention will be illustrated with reference to the following non-limiting figures, wherein:

Figure 1A shows a schematic side view of an exercise device according to the present disclosure;
Figure 1B shows a portion of the exercise device of figure 1A and a trajectory along which a pedal may repeatedly move;
Figures 2A, 2B, and 2C show examples of pedal displacement as a result of distortion events;
Figure 3 shows a further example of the pedal displacement in a distortion event;
Figure 4 shows a schematic representation of forces that may be exerted by a user on the pedal during different portions of the trajectory;
Figure 5A shows, in a perspective view, a crank in an embodiment according to the present disclosure;
Figure 5B shows a bottom view of the crank of figure 5A;
Figure 5C shows a side of the crank of figure 5A that, when the crank is mounted to the exercise device, faces a frame of the exercise device;
Figure 5D shows an exploded view of the crank of figure 5A;
Figure 5E shows the crank of figure 5A while an inner crank body part is removed;
Figure 5F shows a part of the crank of figure 5A while an outer crank body part is removed;
Figure 6 schematically shows an exercise device in another embodiment according to the present disclosure;
Figures 7A and 7B show, in perspective views from different angles, another embodiment of a crank according to the present disclosure;
Figure 7C shows the crank of figures 7A and 7B in a bottom view;
Figure 7D shows a side of the crank of figures 7A and 7B that, when the crank is mounted to the exercise device, faces away from a frame of the exercise device;
Figure 7E shows an exploded view of the crank of figures 7A and 7B;
Figure 7F shows a perspective view of parts shown in figure 7E that, in use, may move in order to cause distortional motion of the pedal;
Figures 7G illustrates a pedal mounting part in a base position;
Figure 7H illustrates a pedal mounting part in a distorted position;
Figures 8A and 8B show, in perspective views from different angles, a further embodiment of a crank according to the present disclosure;
Figure 8C shows a top view of the crank of figures 8A and 8B;
Figure 8D shows a side of the crank of figures 8A and 8B that, when the crank is mounted to the exercise device, faces away from a frame of the exercise device;
Figure 8E shows an exploded view of the crank of figures 8A and 8B;
Figure 8F shows a cross section A-A' indicated in figure 8C;
Figures 8G and 8H illustrate positions of a pedal mounting part during distortional motion of the pedal;
Figure 9A shows an exploded view of a crank in a next embodiment according to the present disclosure;
Figure 9B shows a pedal mounting part and parts of a distortion device that are also shown in figure 9A;
Figures 9C, 9D, and 9E show positions of a pedal mounting part and pedal axle during distortional motion of the pedal;
Figure 10A shows an exploded view of a yet further embodiment of a crank according to the present disclosure;
Figures 10B and 10C show, in a perspective view, a pedal mounting part and parts of a distortion device that are also shown in figure 10A;
Figures 10D, 10E, 10F, and 10G illustrate positions of a pedal mounting part and pedal axle during distortional motion of the pedal;
Figure 11A shows a crank in a yet other embodiment according to the present disclosure;
Figure 11B shows, in an exploded view, the crank of figure 11A;
Figure 11C shows a side of the crank of figure 11A while an inner crank body part is removed, with a pedal mounting part in a base position;
Figure 11D shows a side of the crank of figure 11A while an inner crank body part is removed, with a pedal mounting part in a distorted position;
Figure 11E shows a detail of figure 11C; and
Figure 12 schematically shows an embodiment of a method of operating an exercise device according to the present disclosure.

DETAILED DESCRIPTION

[0061] Figures 1-12 relate to exercise devices or parts thereof. An exercise device may e.g. be a bicycle. Bicycling is a form of transport often used for leisure or commuting. The recent uptake of e-bikes enables many elderly or differently-abled to regularly use bicycles. Many countries have infrastructure that support regular use of bicycles. At the same time, the aging population requires novel solutions to combat the increasing rate of fragility fractures. Although conventional bicycling is a non-weight bearing exercise, the present disclosure illustrated with reference to figures 1-12 provides methods and devices (and parts thereof) that can be used for improving bone strength while bicycling. Thus, among other objectives, the present disclosure aims to offer the possibility of improving bone strength without significant interference or changes of lifestyle.

[0062] The present disclosure generally relates to an exercise device that can be provided with a pedal, such as a bicycle (e.g. depicted in figure 6). The disclosure also relates to other types of exercise devices, e.g. a stationary exercise device that remains on one and the same place during exercising (e.g. depicted in figure 1A). The term pedal may be interpreted broadly, and may cover a wide range of elements that are arranged for receiving a force exerted by a user of the exercise device. The exercise device includes a distortion device that is arranged to mechanically couple to the pedal for generating repeated distortional motion of the pedal. Such distortional motion may be superposed on the conventional movement along a trajectory of the pedal during exercising. The distortional motion may optionally influence the trajectory, in particular a shape of the trajectory, along which the pedal moves. The distortional motion may be controlled to improve a bone strength of the user of the exercise device.

[0063] The distortion device is arranged to control an intensity and/or direction of the distortional motion dependent on a position of the pedal along the trajectory. Alternatively, or additionally, the distortion device is arranged to control the intensity and/or direction of the distortional motion dependent on a force exerted on the pedal along the trajectory. The intensity and/or direction varies along the trajectory. Thus, as the pedal moves along the trajectory, the intensity and/or direction is controlled to vary. Such variations may be repeated, e.g. may be about similar, preferably are substantially equal, each time the pedal moves along the trajectory. The distortional motion may be substantially coupled to a position of the pedal along the trajectory and/or to an exerted force level. Alternatively, the distortional motion may be repeated e.g. at another position along the trajectory and/or with an intensity and/or direction that differs from an earlier distortional motion. According to a further aspect of the present disclosure, the distortion device generates the distortional motion at one or more, e.g. two or three, predetermined positions of the pedal along the trajectory that is repeatedly followed by the pedal.

[0064] The exercise device preferably is provided with a crank that can be rotated, while the pedal is mounted to the crank. Embodiments of a crank are illustrated with reference to figures 5A-5F and 7A-11E. In such an embodiment, the pedal may follow a circular or elliptical trajectory, or another trajectory, closed in itself. Yet further aspects of the present disclosure are directed respectively to the crank and to the distortion device. For example, a yet further aspect of the present disclosure is directed to the crank in assembly with the distortion device and/or parts thereof. Parts of the distortion device, such as one or more, e.g. two or three, actuation arms and possibly also an energy source such as a battery, electric wiring and/or one or more actuators, may be provided on and/or in the crank, preferably in a crank cavity. Such a cavity may be substantially surrounded by a crank body. The crank body optionally forms a crank arm. Thus, a bell crank may be provided. Integrating parts of the distortion device with the crank, enables generation of the distortional motion close to the pedal. As a result, the distortional motion can be directed primarily, i.e. for a relatively large part, to the limb that is moving the pedal mounted to the crank.

[0065] The crank and the distortion device may enable predetermined distortional motion that is especially useful on a bicycle that is used regularly, e.g. for regular commuting to work. In this way, beneficial effects of the distortional motion may be accessible relatively easily. After all, the bicycle is a method of transportation that is popular and is often used by many users. The term transportation used herein may include different kinds of use of the bicycle wherein the user and bicycle are displaced together as a whole. The user does not have to schedule and spend time for training especially directed to preventing or curing bone fragility, but may reach a beneficial effect more easily during biking.

[0066] The embodiments described herein with reference to the figures are directed to various exercise devices provided with a crank, preferably with two similar cranks (e.g. a crank set comprising a left side crank and a right side crank). The cranks disclosed herein in relation to the exercise device however may be regarded as being disclosed on itself as well. Similarly, the distortion device and parts thereof, which may be disclosed herein in relation to the exercise device and/or the crank, may be regarded as being disclosed on itself as well, optionally in assembly with the crank. Preferably, the crank and the distortion device are employed on existing bicycles that are known as such. Thus, cranks and distortions devices according to the present disclosure may be incorporated into different frame geometries from different manufacturers of exercise devices. This may be independent of frame design and may be possible for existing bicycles.

[0067] The present disclosure provides a crank that allows distortional displacement of the pedal relative to a body of the crank. Such cranks are illustrated e.g. with reference to figures 5A-5F and 6A-11E. This type of pedal displacement may decouple the distortional component of the pedal movement from significant distortional torque on the crank axle (or, in other words, the crankshaft). In this way, the distortional motion may also be substantially decoupled from the other crank's arm. Thus, the transfer of distortional motion to the other leg of the user may be diminished or substantially prevented. Diminishing or preventing such transfer may be useful for a recovery leg phase (or, in other words, during a retracting trajectory portion of the pedal) with a relatively low foot-pedal contact force. This may improve the safety and stability of the leg in the recovering phase. It also creates the ability to apply loading with left-right independence and specific control.

[0068] The present disclosure relates to mechanical stimulation of the pedal to realise the distortional motion, via intermittent, continuous and/or single phase impacts. Mechanical componentry may be employed that preferably include components for storage and conversion of potential energy, in combination with electromechanical, electromagnetic, pneumatic, and/or hydraulic actuation. Mechanical components may, partly or completely, be contained and incorporated inside the crank and may reach the pedal-pivot point where a pedal mounting part may be positioned. In this way, a specific mechanical impact profile during the entire crank arm rotation may be provided. In embodiments utilizing electrical power for impact generation, a bottom bracket assembly of the exercise device may be modified to include a slip ring that allows transfer of electrical energy to the rotating cranks. Energy for generating the distortional motion may e.g. be obtained from a battery, such as a battery of an e-bike. Optionally, a battery is contained within the crank cavity. Electrical energy may be delivered towards the crank arm via the crankshaft and a slip ring assembly. The cranks may contain such components without having to substantially alter a position of a user, e.g. a cyclist, on the exercise device.

[0069] The trajectory includes an extending trajectory portion wherein the pedal moves away from the user support and includes a retracting trajectory portion wherein the pedal moves towards the user support. In an embodiment, the distortion device is arranged for controlling the intensity of the repeated distortional motion so that, during the repeated motion of the pedal along the trajectory, the intensity is larger in the extending trajectory portion than in the retracting trajectory portion. Thus, the exercise device enables that, in use, a larger intensity is associated with a larger exerted force. The intensity may be proportional to the force exerted by the user on the pedal relative to a maximum of said force, during at least a portion of the trajectory.

[0070] More in general, a controller of the distortion device may be arranged for generation by the distortion device of the distortional motion when the exerted force is above a force threshold, e.g. a force threshold of 50 N or of 100 N. Preferably, the force threshold is above a passive weight of a user's leg resting on the pedal, so that distortional motion is only exerted if a user actively pushes the pedal. Alternatively, or additionally, the force threshold may be specified as a percentage, e.g. 70%, 80%, or 90%, of an average maximum force (including passive weight plus actively applied force) exerted by the user during one or more earlier rotations of the pedal. Thus, preferably, the distortional motion may only be generated when the exerted force exceeds a force threshold. Thus, preferably, distortional motion is not generated when the exerted force is below the force threshold. This may give a user a feeling of control over the occurrence of the distortional motion. Of course, other ways of achieving that the intensity is proportional to the exerted force are possible as well.

[0071] The present disclosure is also directed to various forms of beneficial distortional motion, e.g. illustrated with reference to figures 2A-3. Prior art has described continuous and about sinusoidal loading of the pedal, which is limited in its control and effects. The present disclosure however enables a better control of the acceleration of the distortional motion. The total strain, the duration of the strain (or, in other words, the strain period), and the strain rate, are three factors that are believed to influence bone healing. Loading acceleration e.g. will influence strain rate experienced at the bone micro-scale. The control of these factors during the impact events, rather than only two parameters (like when applying a sinusoidal profile defined by frequency and amplitude only), has greater potential for bone strength improvements (see e.g. Wendy M. Kohrt et al., "Physical Activity and Bone Health", Medicine & Science in Sports & Exercise, 2004: American College of Sports Medicine, p. 1985-1996). The present disclosure allows, for example, high strain-rates during the compression phase of the relative pedal movement, and lower strain-rates during the decompression phase of the impact event. Such control also improves safety and useability as the pedal acceleration away from the foot can be made slower than the acceleration into the foot, improving foot-pedal contact maintenance.

[0072] The present disclosure e.g. is directed to one or more impact events that may be individually controlled. A controller of the distortion device may be arranged for controlling such distortion events (or, in other words, impact events). The controller, preferably in combination with a sensor of the distortion device, may be arranged for timing the distortion events at beneficial positions of the pedal along the trajectory. The possibility of applying timed impact events to the lower body of a bicycle user, with the purpose to reduce fragility fractures in the lower limbs and pelvis region by increasing the mechanical properties of these bones (including density and geometric adaptations), opens up a broad range of possibilities of effectively improving bone strength in an accessible way.

[0073] In an embodiment, the distortion device is arranged for generating a predetermined number of impact events, preferably during a predetermined time period, e.g. 150 impact events on each leg per day. If the predetermined number is reached, the distortion device may stop, or at least reduce, generating further distortion events until the time period, e.g. the day, has ended. This creates a greater level of user satisfaction and accomplishment, so the user does not avoid the bicycle to avoid continuous loading. A limit to the number of impact events may be beneficial, as well as distributing loading of a fragile bone over multiple days rather than the same accumulated number in a single day. A daily limit may also preserve a battery of the distortion device and moving components. Furthermore, it would provide the user a sense of satisfaction of completion of daily treatment/prevention.

[0074] In e.g. cases where a known disease, injury or risk is present, and/or where a suitable resolution bone imaging modality can be used, the loading conditions can be determined using analysis of the individual's lower limb bone and pelvis quality. The loading conditions are then adjusted according to the mechanical analysis of the bone to apply loading that is most efficacious for the specific patient. This benefit allows users with highly fragile bone, e.g. post-trauma or as a result of severe osteoporosis, to have loading relative to their current condition, and a change in the loading conditions as bone becomes more stable, strong, or dense. This can also be left-right specific to factor in the user's needs, e.g. in case of a fracture on a left or right leg only.

[0075] The present disclosure further relates to a method of operating an exercise device. The disclosure further relates to a method of using an exercise device and a method of exercising by means of an exercise device. Preferably, the exercise device is a bicycle that is arranged for transporting the user. In this way, the benefits offered by the bicycle against osteoporosis can be achieved during everyday life, wherein the bicycle is used for transportation. In this way, a significant barrier hindering use of the exercise device can be removed. However, the exercise device may also be used beneficially as an indoor exercise device.

[0076] Use herein of "a" or "an" does not exclude a plurality. Terms like couple, attach, mount, connect etc. and their conjugations used herein are to be interpreted broadly. E.g., mechanically coupling one part to another part may include mechanically coupling these parts by means of at least one further part positioned in between said one part and said another part. Unless expressly indicated otherwise, coupling, attaching, mounting, connecting etc. may lead to slidable, rotatable, releasable, and/or fixed couplings, attachments, mountings, connections, etc. The term bicycle includes e-bikes and other types of bicycles wherein the user is assisted in pedalling, i.e. wherein the user exerts only part of the force needed for pedalling and/or motion. The term mechanical is to be interpreted broadly. Reference to a mechanical coupling e.g. includes hydraulic, electromagnetic, and/or pneumatic couplings. The embodiments described herein illustrate various features. Features described for an embodiment, may be combined with features of another embodiment. The invention is not limited to the embodiments described with reference to the figures, and may be embodied in other ways as well. SI-units are used herein, like meter (m), second (s), Hertz (Hz), kilogram (kg), and Newton (N). Length may e.g. be expressed in meter or millimeter (mm). Time may e.g. be expressed in seconds or milliseconds (ms).

[0077] Figure 1A shows an exercise device 2, in this embodiment a stationary exercise device 2. The stationary exercise device may contain parts of a road bike or another type of bicycle that can be separated from the exercise device 2 and can be used for transportation. Alternatively, the exercise device 2 may be exclusively designed for and directed to stationary use, e.g. in a gym. The exercise device 2 may be provided with a frame 3 and a user support 4. The user support is arranged for supporting a user of the exercise device 2, such as a person visiting the gym or a cyclist that wishes to exercise indoors and/or under well-defined conditions. As shown in figure 1A, the user support 4 may be a seating such as a saddle. During use of the exercise device, the user may rest on the user support. The user may e.g. rest directly on the saddle, preferably supported via the saddle and a saddle pin, on the frame, e.g. on an upper end portion 6 of a seat tube 10 or another upright support structure. Thus, alternatively to the seating, e.g. the saddle pin 8 or the upper end portion 6 of the seat tube 10 (or another upright support structure) of the frame 3 may also be regarded as user support. Other frame portions that, in use, are positioned well above the trajectory, may also be regarded as user support.

[0078] The exercise device 2 may be provided with a pedal 12. The pedal 12 may be generic and known as such, and is arranged for receiving a force exerted on the pedal 12 by the user of the exercise device 2. Although the pedal 12 may be omitted, when provided on the exercise device the pedal 12 allows repeated motion of the pedal 12 relative to the user support 4 along a trajectory 14. This can e.g. be achieved by rotatably mounting the pedal 12 to the crank 16. Thus, in use, the pedal may repeatedly move along the trajectory 14, i.e. move along the trajectory a plurality of times. The trajectory 14 shown in figure 1A is closed in itself, so that the pedal makes revolutions along the trajectory 14. Moving along the trajectory 14 once may coincide with a revolution of the pedal 12. The trajectory 14 may e.g. be substantially circular or may be substantially elliptical.

[0079] As schematically shown in figure 1B, the trajectory 14 may include an extending trajectory portion 14A wherein the pedal 12 moves away from the user support 4. In the extending trajectory portion, a leg of the user that exerts a force on the pedal, may extend (or, in other words, may stretch). Or, viewed in another way, a bending of the knee of said leg may decrease during the extending trajectory portion. A start of the extending trajectory portion 14A may be called the 12 o'clock position. An end of the extending trajectory portion may be called the 6 o'clock position. The pedal may repeatedly move along the trajectory 14 unidirectionally, e.g. repeatedly clockwise or repeatedly anti-clockwise or repeatedly up and down. In the example of figure 1B, in use the pedal 12 moves clockwise in the rotational direction of arrow 18.

[0080] The trajectory 14 may also include a retracting trajectory portion 14B wherein the pedal moves towards the user support 4. In the retracting trajectory portion, a leg of the user that exerts a force on the pedal 4, may retract. Or, viewed in another way, a bending of the knee of said leg may increase during the retracting trajectory portion 14B. A position along the trajectory where the knee starts, or about starts, bending may be called the 6 o'clock position, or 180 degrees. A position along the trajectory where the knee starts, or about starts, stretching may be called the 12 o'clock position, or 0 degrees. Thus, a pedal position along the trajectory 14 may be expressed by an angle α along the trajectory that is zero at the pedal position where the knee bend changes, or about changes, from increasing to decreasing.

[0081] The end of the extending trajectory portion 14A may coincide with the start of the retracting trajectory portion 14B. Alternatively, or additionally, the end of the retracting trajectory portion 14B may coincide with the start of the extending trajectory portion 14A. The extending trajectory portion 14A and the retracting trajectory portion 14B may have a substantially equal length. The extending trajectory portion 14A and the retracting trajectory portion 14B may together take up the whole trajectory 14, e.g. one complete revolution of the pedal. The extending trajectory portion 14A and/or the retracting trajectory portion 14B may have a length equal to about one half of the trajectory length, e.g. may cover a 180 degree angle.

[0082] Other definitions of the trajectory portions are possible as well. Alternatively, the extending trajectory portion and/or the retracting trajectory portion may have a length equal to about one third of the trajectory length, e.g. may cover a 120 degree revolution. Thus, a start of the retracting trajectory portion may be called the 7 o'clock position. An end of the retracting trajectory portion may be called the 11 o'clock position. A start of the extending trajectory portion may be called the 1 o'clock position. An end of the extending trajectory portion may be called the 5 o'clock position. The extending and retracting trajectory portion can alternatively be defined by an upward angle β and a downward angle β with the horizontal H (the upward angle β being indicated in figure 1B). In an embodiment, the crank in the extending trajectory portion and/or in the retracting trajectory portion, makes an upward or downward angle β of at most 60 degrees with the horizontal.

[0083] The exercise device 2 includes a distortion device. The distortion device is not drawn in figure 1A, but embodiments will be described e.g. with reference to figures 5A-12. The distortion device is arranged to mechanically couple to the pedal 12 for generating repeated distortional motion of the pedal 12. The term "repeated" refers to repetition of distortional motion that occurred during movement along the trajectory in one or more previous revolutions. This may occur at the about the same pedal position along the trajectory or at another pedal position along the trajectory. This may occur by means of a similar, or substantially the same, distortion event or by means of another distortion event. This may occur with or without non-distorted pedal revolutions in between. Thus, optionally, as a result of the distortional motion, a plurality, e.g. two or more than two, of subsequent revolutions of the pedal may be along different trajectories. More in general, the crank may be arranged to allow, when the pedal is provided on the exercise device and is mechanically coupled to the crank, translational motion of at least part of the pedal relative to a body 30 of the crank. Thus, as a result of the distortional motion, the pedal may be translated relative to the crank body 30.

[0084] The distortional motion may generally include one or more distortion events 20, i.e. at least one distortion event 20, along the trajectory 14. A majority, preferably at least 80 %, of the pedal displacement as a result of the distortional motion may be contained, along the trajectory, in the one or more distortion events. The one or more distortion events 20 may be distributed along the trajectory 14. The distortional motion may e.g. be repeated during each revolution of the pedal 12 along the trajectory 14, or may e.g. be repeated during a revolution after one or more intermediate revolutions with no or reduced distortional motion have passed, e.g. after at least two or at least five revolutions have passed without distortional motion. Thus, a sequence of one revolution with distortional motion followed by one ore more, e.g. at least one, at least two, or at least five, revolutions without distortional motion, may be applied repeatedly.

[0085] The distortion device is arranged for controlling the intensity of the repeated distortional motion. The intensity may be an amplitude of the distortional motion, preferably along a certain direction (e.g. vertically or perpendicular to a longitudinal crank direction). Alternatively, or additionally, the intensity may be a duration of the distortional motion, an event count of the distortional motion (e.g. a number of distortion events of the distortional motion) per unit of time, an acceleration of the distortional motion, a jerk of the distortional motion, work done in the distortional motion and/or power used by the distortional motion. Thus, for example, a higher intensity may be reached by having a higher amplitude (e.g. a maximum distortional travel away from a base position during a distortion event) of the distortional motion. Alternatively, or additionally, a higher intensity may be reached by a higher event count per unit of time of the distortional motion, i.e. a higher number of distortion events per unit of time. Preferably, the higher intensity is reached by having a higher amplitude and/or a higher acceleration of the distortional motion. More in general, an intensity of the distortional motion preferably is an amplitude and/or acceleration of the distortional motion.

[0086] As a result of the control, during the repeated motion of the pedal 12 along the trajectory 14, the intensity is larger in the extending trajectory portion 14A than in the retracting trajectory portion 14B. Thus, preferably, the amplitude and/or acceleration of the distortional motion is larger in the extending trajectory portion 14A than in the retracting trajectory portion 14B. Alternatively, or additionally, such a higher intensity can be realised for example by a number of distortion events in the extending trajectory portion 14A being larger than a number of distortion events in the retracting trajectory portion 14B. The retracting trajectory portion may be substantially free from distortion events.

[0087] The distortional motion may generally be predetermined. Thus, the distortion device may be arranged for controlling the intensity of the repeated distortional motion in a predetermined way. The distortional motion may be similar for each repetition of the pedal 12 along the trajectory 14, or for a sequence consisting of a plurality of subsequent repetitions of the pedal 12 along the trajectory 14. A position of the pedal 12 at which the distortion events occurs along the trajectory 14, may be predetermined as well. In an embodiment of predetermined distortional motion, the distortion device may be arranged to control the intensity and/or direction of the distortional motion to occur substantially randomly, within predetermined restrictions. For example, the distortional motion may be generated at a random pedal position in a portion of the extending trajectory portion (e.g. α being a in range from 60 degrees to 120 degrees or from 70 degrees to 150 degrees). Thus, the distortion device may be arranged for controlling the pedal position(s) α at which the repeated distortional motion occurs along the trajectory.

[0088] The distortional motion (e.g., the distortional displacement and its first, second and/or third time derivatives) may lead to a displacement, velocity, acceleration, and jerk of the pedal 12, superposed on the movement of the pedal along the trajectory. Figures 2A, 2B, and 2C show examples of pedal displacements of distortion events, i.e. pedal displacements as a result of the distortional motion. Along the horizontal axis is the angle α, indicating the position of the pedal along the trajectory 14. Along the vertical axis is the displacement d of the pedal 12 as a result of the distortional motion. In the example of figure 2A, the number of distortion events 20 along the trajectory is two. In the example of figure 2B, the number of distortion events 20 is three. In the example of figure 2C, the number of distortions events 20 is three.

[0089] Figure 3 shows a further example of the pedal displacement d in a distortion event 20. The distortion event 20 may include a distorting portion 20A and a normalising portion 20B. In the distorting portion 20A, the distortional motion may move the pedal away from a first base position (indicated by $d_{0,1}$ in figure 3) to a position of maximum distortion (indicated by d_{max} in figure 3). In the normalising portion, the pedal 12 may move away from the position of maximum distortion towards a second base position $d_{0,2}$. The first and second base position may be substantially equal, but may be different as well. The maximum distortion d_{max} may be substantially equal for a plurality of distortion events, or may be different between two or more distortion events.

[0090] In a distortion event 20 as shown in figures 2A-C and 3, a maximum pedal displacement d as a result of the distortional motion may be at least 3 mm. The maximum pedal displacement d_{max} in a distortion event as a result of the distortional motion may be at most 25 mm. A maximum pedal displacement in the distorting portion 20A preferably is at least 4 mm, and/or at most 15 mm. This enables distortional motion that is effective for improving the user's bone strength (the displacement is not too small) and is still comfortable for the user (the displacement is not too large).

[0091] In a distortion event, an absolute value of a maximum pedal acceleration as a result of the distortional motion may be at least 15 m/s^2 and/or at most 60 m/s^2. An absolute value of a maximum pedal acceleration of at least 15 m/s^2, or preferably 20 m/s^2, enables distortional motion that is effective for the user's bone strength (taking into account possible signal attenuation, in particular from the pedal through the foot and across the leg and pelvis region). A pedal acceleration of at most 60 m/s2, or preferably at most 45 m/s^2, enables distortional motion that may still be comfortable for the user. Additionally, or alternatively, an absolute value of a maximum pedal jerk as a result of the distortional motion is at least 400 m/s^3 and/or at most 4000 m/s^3, preferably at least 800 m/s^2 and/or at most 2500 m/s^2.

[0092] The values for acceleration, jerk, duration, force, and displacement of the distortional motion mentioned in the present disclosure may be defined relative to the body of the crank. Said values may be determined, in particular for an exercise device, method of providing an exercise device, or distortion device presented herein, with a passive weight of 8 kg resting on the pedal so that it is moved vertically by the distortional motion. In use, the acceleration, jerk, duration, force, and displacement actually occurring may be different, e.g. in view of the possibility of some horizontal movement and in view of the portion of the force actively exerted on the pedal by the user in addition to the force resulting from a weight of the user's leg resting on the pedal. Alternatively, in particular in a method of exercising by using an exercise device, said values may be determined in use, e.g. by means of a displacement sensor arranged for determining a pedal position relative to the crank body. The absolute value of the maximum pedal acceleration may be larger in the distorting portion 20A of a distortion event 20 than in the normalising portion 20B of the same distortion event 20. Examples of such non-symmetrical distortion events are e.g. shown in figure 2A.

[0093] In the distortion events of figure 2A, a maximum pedal velocity and/or a maximum absolute value of acceleration, as a result of the distortional motion, in a direction towards the user support is larger than a maximum pedal velocity and/or a maximum absolute value of acceleration, as a result of the distortional motion, in an opposite direction away from the user support. A lower pedal velocity resulting from the distortional motion when moving away from the user support, may be more comfortable to the user.

[0094] A duration of a distortion event may be at least 10 ms and/or at most 50 ms, preferably at least 15 ms and/or at most 30 ms. A start of a distortion event may be defined by a pedal displacement, as a result of the distortional motion, reaching 10 % of the total distance when moving towards the user support from the first base position to the position of maximum distortion, before reaching said maximum distortion. An end of a distortion event may be defined by a pedal displacement, as a result of the distortional motion, reaching 90 % of the total distance when moving away from the user support from the position of maximum distortion to the second base position, after reaching said maximum distortion.

[0095] The combination of the number of distortion events, the absolute value of the maximum acceleration during a distortion event, and/or the maximum displacement during a distortion event, may define a distortional effect generated on a bone of the user as a result of the distortional motion. Lower limits for the distortional effect generated on a bone, enable reaching beneficial effects to the bone strength of the user. The motion may be measured by fixing one or more accelerometers and/or other motion or displacement sensors to the pedal, and optionally also to the crank body. The effect may be estimated by fixing one or more accelerometers or sensors to the skin at the bone region of interest.

[0096] In an embodiment, a first distortion event at a pedal position α of about 30 degrees may lead to a peak distortional acceleration generated on a bone of the user as a result of the distortional motion of about 20 m/s^2, a second distortion event at a pedal position α of about 90 degrees may lead to such a distortional acceleration of about 45 m/s^2, and/or a third distortion event at a pedal position α of about 150 degrees may lead to such a peak distortional acceleration of about 30 m/s^2. Optionally, a fourth distortion event in the retracting trajectory portion may lead to such a peak distortional acceleration of about 20 m/s^2.

[0097] During use of an exercise device, it could happen that the pedal of the exercise device is distorted only marginally and possibly uncontrolled, e.g. leading to a pedal maximum displacement smaller than 1 mm and/or a maximum pedal acceleration smaller than 5 m/s^2. Such distortions could e.g. be caused by external circumstances while not being generated by the distortion device. Distortions meeting one or more of these criteria, and/or other externally caused distortions that are not generated by the distortion device, could be disregarded as distortion events in the sense of the present disclosure.

[0098] Figure 4 shows a schematic representation of forces that may be actively exerted by a user on the pedal during different portions of the trajectory 14, when the exercise device e.g. is a bicycle and the trajectory is approximately circular or elliptical. Figure 4 shows arrows representing forces 24.i (i=1, ..., 6) that may typically be exerted during a portion of the trajectory by different groups of muscles (variations may e.g. be caused by the cycling shoe used and its mechanical coupling to the pedal). Arrow 24.1 represents forces exerted by hip extensor muscles. Arrow 24.2 represents forces exerted by knee extensor muscles. Arrow 24.3 represents forces exerted by ankle plantar flexor muscles. Arrow 24.4 represents forces exerted by ankle dorsiflexor muscles. Arrow 24.5 represents forces exerted by knee flexor muscles. Arrow 24.6 represents forces exerted by hip flexor muscles.

[0099] Hip extensor muscles and knee extensor muscles are relatively powerful. As illustrated in figure 4, these muscles typically are active in the extending trajectory portion (o degrees $\leq \alpha \leq$ 180 degrees). Thus, a force repeatedly exerted by the user on the pedal along the trajectory, e.g. during each revolution of the pedal along the trajectory, will normally be larger in the extending trajectory portion compared to the retracting trajectory portion. The maximum force along the trajectory is typically reached during the extending trajectory portion, instead of during the retracting trajectory portion. The force repeatedly exerted by the user on the pedal along the trajectory relative to a maximum force along the trajectory, will normally also be larger in the extending trajectory portion compared to the retracting trajectory portion.

[0100] It may thus be clear that the exercise device 2 enables preferencing a relatively large intensity to occur when a relatively high proportion of the leg and hip muscles are in contraction and a relatively large force on the pedal exists. Thus, the distortion device may be arranged for controlling the intensity of the repeated distortional motion so that, during at least a portion of the trajectory, the intensity is proportional to the force exerted by the user on the pedal relative to a maximum of said force during at least a portion of the trajectory. This enables strain and/or strain rates in lower limb bones and the pelvis caused by the distortional motion of the pedal that are effective against osteopenia and osteoporosis.

[0101] The distortion device may e.g. be arranged for generating a relatively strong impact event at or near the 3 o'clock position, and a somewhat lower stress impact event at or near the 2 and/or 4 o'clock positions. The controller enables biomechanical considerations to optimise impacts in different leg positions and/or different applied acceleration levels. Moreover, as a result of the relatively large force exerted by the user when a distortion event occurs, a foot of the user may be in firm contact with the pedal. Thus, a relatively good transfer of the distortional motion to the leg may be achieved. This may also enable an improved control of the strain rate in the lower limb bones and pelvis.

[0102] A positive effect may be enhanced as, in the extending trajectory portion, distortional loads may be applied in a preferred direction, e.g. along a long axis of the tibia and/or tailored for loading on the hips. When the leg extends, an angle between the longitudinal direction of the tibia and a longitudinal direction of the femur will decrease. A relatively small angle between the tibia and the femur may promote an effective transmission of the pedal's distortional motion through the leg. Thus, having the intensity larger in the extending trajectory portion - in particular in the second half of the extending trajectory portion - than in the retracting trajectory portion, may enhance a positive effect of the distortional motion.

[0103] Preferably, the number of distortion events along the trajectory is at least one and/or at most ten. For a typical cadence of about 60 rotations per minute, a maximum of 10 distortion events would translate into an event count per unit of time of 10 Hz, averaged over the trajectory time. An event count of 1-10 Hz may support net positive bone formation (see e.g. Yeou-Fang Hsieh Charles H. Turner, "Effects of Loading Frequency on Mechanically Induced Bone Formation", Journal of Bone and Mineral Research, Volume 16, Issue 5, 2001). However, intermittent random loading may also be beneficial. For example, jumping with seemingly varied and low frequencies can increase bone properties relatively quickly in humans. As such, there are many types of loading events that will be beneficial. Overall, above a threshold, loading that is outside the normal loading experienced by older persons, especially those who do not participate in load inducing sports or activities, may have benefits against the onset or presence of osteoporosis.

[0104] In an embodiment, the number of distortion events along the trajectory is at least one and/or at most three. A regular cyclist typically has a cadence in the range of 60-100 revolutions per minute (RPM). This regularly corresponds to an average event count per unit of time between 1 Hz (60 RPM, single event/revolution) to 5 Hz (100 RPM, 3 events/revolution). Preferably, a number of distortion events in the extending trajectory portion is at least one and/or at most three. This enables focussing the distortional motion during a portion of the trajectory wherein the force exerted by the user is near a maximum, e.g. at a pedal position α along the trajectory 14 between 50 degrees and 170 degrees.

[0105] The user may wear a shoe that can be mechanically coupled to the pedal. This may facilitate an efficient reception of the force exerted on the pedal by the user. In order to achieve such coupling, the sole of the shoe may e.g. be provided with a cleat and the pedal may include a cavity for receiving the cleat. The pedal may include a resilient or spring-loaded member that is arranged to engage with the cleat and lock the cleat to the pedal. This will normally also enable a user to pull the pedal along the trajectory in the retracting trajectory portion. As a result, the force exerted on the pedal in the retracting trajectory portion may even become negative. In the present disclosure, a negative force exerted on the pedal is considered to be smaller than a positive force exerted on the pedal, pushing the pedal along the trajectory.

[0106] It is recognised that many exercise devices will not be arranged to achieve such coupling between the pedal and the shoe of the user. Instead, a user often places one of his or her foots loosely on the pedal. Thus, by having the intensity to be larger in the extending trajectory portion than in the retracting trajectory portion, the exercise device 2 may also prevent loss of contact or another undesirable movement between the pedal and the user as a result of the distortional motion. The higher force exerted in the extending trajectory portion may reduce a risk of moving a foot of the user off the pedal as a result of the distortional motion. The lower intensity in the retracting trajectory portion may reduce a risk of moving the foot off the pedal.

[0107] The distortional motion can, in general, be generated in various ways, preferably by adapting the crank 16. Thereto, unlike cranks commonly used on bicycles, the crank 16 may be provided with a crank cavity. The crank cavity may contain parts of the distortion device. The crank may e.g. include a crank body that substantially encloses the crank cavity. Thus, the crank cavity may be provided inside the crank body. The crank body may thus form a housing of parts of the distortion device, e.g. an actuator and/or one or more actuation arms of the distortion device. Via such parts, embodiments of the distortion device may be arranged to mechanically couple to the pedal 12 for generating repeated distortional motion of the pedal 12. In the embodiments of figures 5A-5F and 7A-11E, the crank is arranged for allowing at least translational motion of the pedal 12 relative to the crank body 30. Thus, the pedal 12 can translate relative to the crank body 30.

[0108] Figure 5A shows, in an embodiment, a crank 16 according to the present disclosure. Figure 5B shows a bottom view of the crank 16. Figure 5C shows a side of the crank 16 that, when the crank is mounted to the exercise device, faces the frame of the exercise device. The crank 16 may include a crank body 30. The crank body 30 may include an inner crank body part 30A that, in use, faces the frame of the exercise device. The crank body 30 may also include an outer crank body part 30B that, in use, faces away from the frame of the exercise device. The crank 16 may be provided with a mounting arrangement 43 for a chain ring. The mounting arrangement 43 may be provided with holes 46 for chain ring bolts. A length L_1 of the crank body 30 may be in a range from 200 to 250 mm. A span width W_1 of the crank body 30 may be in a range from 20 to 80 mm, preferably in a range from 30 to 60 mm.

[0109] A pedal, e.g. the pedal 12 illustrated in figure 1A, when provided on the exercise device, may be mechanically coupled to the crank 16 to allow rotational motion of at least part of the pedal relative to the crank body 30. Thereto, the crank may have received a pedal mounting part 40 that is arranged for mounting the pedal 12 to the crank 16. A pedal axle of the pedal may be fixed to the pedal mounting part 40, e.g. via a threaded connection. The pedal may be provided with a bearing around the pedal axle so that a remainder of the pedal can rotate around the pedal axle. The rotation around the pedal axle may enable the pedal to stay in a stable, preferably substantially horizontal, orientation, attached to a foot of the user. The pedal may thus be provided on the exercise device for repeated rotational motion relative to the user support along the trajectory.

[0110] Figures 5A-5C further show a crankshaft 34 that may be included by the exercise device 2. The exercise device may be arranged to allow rotational motion of the crankshaft 34 relative to the user support. This may be achieved e.g. by means of a hollow bracket 36 (shown in figures 1A and 1B), which can be provided with a bearing through which the crankshaft 34 can rotate. At least part of the bearing may be provided in between a hollow member 38 and the crankshaft. The hollow member 38 may be fixedly mounted inside the bracket 36 of the frame, in order to provide a space with well-defined dimensions for positioning the at least part of the bearing. The crank 16 may be fixed to the crankshaft 34, e.g. by means of a crank bolt 39. The crank and the crankshaft may be separable from each other. Alternatively, the crankshaft and at least part of the crank body 30 may be integrally formed as one part. A distance L_2 (indicated in figure 5C) between a center of the crankshaft 34 and a center of the pedal mounting part 40, may be in a range from 160 to 175 mm.

[0111] The crank 16, preferably the crank body 30, may be provided with a slot 32. The slot 32 may be provided in the outer crank body part 30B and preferably also in the inner crank body part 30A. The slot 32 enables translational motion of the pedal mounting part 40 and the pedal 12 relative to the crank body 30. By means of its dimensions, the slot also constrains the distortional motion of the pedal. Figures 5A and 5C show the pedal mounting part at a base position in the slot 32, which may be a bottom position during the extending trajectory portion. This position may be regarded as corresponding to the first base position $d_{0,1}$ of the pedal, as indicated in figure 3. When the pedal is at a top position in the slot 32 during the extending trajectory portion, the pedal may be regarded to be in the position of maximum distortion (indicated by d_{max} in figures 3 and 5C). Thus, more in general, the distortional motion may move the pedal from the first base position to a distorted position, and preferably back to the second base position.

[0112] The slot may have a longitudinal slot direction 31, along which the pedal may be allowed to move predominantly. As illustrated in figure 5A, the longitudinal slot direction 31 may be slightly curved (in view of the pivotal motion of an actuation arm 42 around a pivotal connection 60). More in general, the longitudinal slot direction may be substantially straight and/or may be curved. I.e., the slot may be substantially straight and/or the slot may be curved. The crank may have a longitudinal crank direction 41 and may have a longitudinal shape. Preferably, the slot 32 is positioned in the crank 16 so that the longitudinal slot direction 31 is transverse, e.g. substantially perpendicular, to the longitudinal crank direction 41. In this way, it may be achieved that a majority of the distortional motion of the pedal relative to the crank body is directed transverse to the longitudinal direction 41 of the crank body 30.

[0113] The crank 16 may be arranged to allow motion, translational motion and optionally also rotational motion, of the pedal mounting part 40 relative to the crank body. Thereto, the crank may have a crank cavity 44 in the crank body 30, arranged to receive the actuation arm 42. Figures 5D-5F show that the actuation arm 42 generally may have a longitudinal shape and may extend along the longitudinal direction 41 of the crank body. Thus, a longitudinal direction of the actuation arm and the longitudinal direction of the crank body may be substantially aligned with each other. When received in the crank cavity 44, the actuation arm 42 may be positioned to mechanically couple to the pedal mounting part 40 for generating distortional motion of the pedal. In the embodiment of figures 5A-5F, the actuation arm 42 is rigidly attached to the pedal mounting part 40. The actuation arm 42 and the pedal mounting part may e.g. be formed out of one piece, may be glued to each other or may be welded to each other.

[0114] In the embodiment of figures 5A-5F, a distortion device of the exercise device may include a cam 50 and a cam follower 52, as illustrated in figures 5D-5F. The cam follower 52 may be formed by the actuation arm 42. Alternatively, the cam follower may be mechanically coupled to the actuation arm 42, preferably by means of a rigid attachment. A distortion device that includes a cam and the cam follower may e.g. be advantageously applied on a stationary exercise device. Such an exercise device may e.g. be used in a gym. The cam and cam follower may provide a robust way of generating repeated distortional motion. As a user of a stationary exercise device will not encounter traffic risks during exercising, a need for turning on and of the distortional motion may be less or may even be absent.

[0115] The cam 50 may define a cam path 54 for the cam follower 52. As visible in figure 5F, the cam path 54 is defined by an outer circumference 56 of the cam 50. The cam follower 52 may be arranged for repeatedly following the cam path 54. Thereto, the cam follower may be attached to the crank, e.g. by means of the pivotable connection 60. The pivotable connection 60 allows the cam follower 52, and in this embodiment also the actuation arm 42, to rotate (or, in other words, turn) with respect to the crank body 30. Thus, the pivotable connection 60 may enable the cam follower to follow the cam path 54. The cam follower may include a cam follower bearing 61 that is in direct contact with the cam 50 along the cam path 54.

[0116] The cam 50 may be rotatably attached to the crank body 30. Alternatively, in another embodiment, the cam 50 may be attached to the crankshaft. In use, the cam 50 may rotate as a result of the rotation of the crank and/or the crankshaft. In the embodiment of figures 5A-5F, a first gear wheel 62 may be provided that is fixedly attached to the frame of the exercise device, preferably to the bracket 36 included by the frame, e.g. via the hollow member 38. The crank may be provided with a second gear wheel 64 that is rotatably attached to the crank. The second gear wheel may be positioned in the crank cavity 44. The second gear wheel 64 may be positioned and sized in orde to engage the first gear wheel 62. As a result of the engagement, the second gear wheel 64 will rotate relative to the crank and the crank body when the crank rotates. The cam may be fixed to the second gear wheel 64. The cam 50 and the second gear wheel 64 may be made out of one piece. Thus, the cam 50 is rotatably attached to the crank 16 so that, in use, the cam 50 rotates relative to the crank 16 and the crank body 30 as a result of the rotation of the crank and/or the crankshaft. The cam 50 may be fixedly attached to the second gear wheel. The cam 50 and the second gear wheel may be made of one piece. Thus, the cam 50 may be rotatably mounted to the crank.

[0117] The cam follower 52 may be resiliently mounted in the crank body 30. Alternatively, the cam follower 52 may be mounted on the crank body 30. A spring between the cam follower and the crank body may e.g. be used for such resilient mounting. The resilient mounting may cause the cam follower to be pushed against the cam, e.g. against the outer circumference of the cam that forms the cam path. Thus, the cam follower, as well as the actuation arm 42, may be spring-loaded in order to continuously push the cam follower against the cam 50, in particular against the cam path. The cam path has a deviation 66 from a circular shape in order to cause the distortional motion as a result of the resiliently mounted cam follower following said deviations. The circular shape may be defined relative to an axis of rotation of the cam, said axis of rotation coinciding with the center of the circular shape. The cam follower may be arranged to mechanically couple to the pedal. In the embodiment of figures 5A-5F, this is achieved via the actuation arm 42 that is attached to the pedal mounting part 40.

[0118] In an embodiment not shown in figures 5A-5F, the distortion device may include a cam that may be fixedly attached to the crank and/or the crankshaft and a cam follower that may be resiliently mounted on the frame. The crankshaft may be mounted in the frame to allow rotational motion of the crankshaft relative to the user support, wherein a spring between the cam follower and the frame may e.g. be used for such resilient mounting. Such resilient mounting may cause the cam follower to be pushed against the cam, e.g. against the outer circumference of the cam that forms the cam path. The cam path has one or more deviations 66 from a circular shape. The cam follower may be arranged to mechanically couple to the pedal mounting part, e.g. through the actuation arm 42. As a result of the one of more deviations, distortional motion of the pedal mounting part - and hence of the pedal - may be achieved.

[0119] Figure 6 shows another embodiment of an exercise device 2, that may be provided with a user support 4 and an upright support structure 10 such as a seat tube. In this embodiment, the exercise device 2 is a bicycle that is arranged for transporting the user. Providing distortional motion on a bicycle used for transporting, e.g. daily commuting to and from work, may enable prevention and/or reduction of osteopenia and/or osteoporosis, in a way that is relatively easily accessible. The exercise device is provided with the distortion device. The distortion device may include a controller 80A, a sensor 80B, and a battery 80D. In figure 6, the controller 80A, the sensor 80B and the battery 80D are shown positioned outside the crank cavity. Optionally, the controller 80A, the sensor 80B and/or the battery 80D may be accommodated in the crank cavity. The sensor may be arranged for generating a sensor signal that is indicative for the force exerted on the pedal 12. The sensor may e.g. be a strain sensor that measures strain in the crank body of the crank. After calibration of the sensor, the measured strain can be translated to the force exerted on the pedal. Alternatively, or additionally, the sensor may be arranged for sensing a position of the pedal 12 along the trajectory. The sensor may be a position sensor, such as a rotary encoder. The position sensor may be arranged for measuring crank position e.g. represented by angle α and/or β (shown in figure 1B), cadence, and rotational direction 18 (shown in figure 1B).

[0120] Examples of sensors that generate a signal that carries information on the pedal position and/or a force exerted on the pedal, are already known as such. Examples of these are sensors are commonly referred to as power meters, which may employ one or more strain gauges. Such sensors may be used as part of the distortion device. The sensor and/or the controller may be positioned on and/or in the exercise device apart from the crank itself. The position sensor, strain sensor or other sensors may generally be arranged to estimate or determine the position of the pedal along the trajectory 14, and preferably also the (rotational) direction 18 of the pedal along the trajectory.

[0121] In the embodiment of figure 6, the distortion device further includes an actuator that is arranged to mechanically couple to the pedal for generating the distortional motion. Embodiments of such actuators will be described with respect to figures 7A-10E. The controller 80A is communicatively connected to the sensor 80B to receive the sensor signal. The communicative connection may be a wired and/or wireless connection, such as an adaptive network technology (ANT) communicative connection or a Bluetooth connection. The controller 80A is also communicatively connected to the actuator for controlling the intensity of the distortional motion by means of a control signal. The communicative connection between the controller 80A and the actuator may be a wired and/or wireless connection, such as an ANT or a Bluetooth connection.

[0122] The controller 80A may be arranged for generating the control signal based on the sensor signal. In this way, the timing of the intensity may be linked to the trajectory time or the pedal cadence (usually expressed in rotations per minute). Thus, the control signal may be adjusted to the sensor signal. By basing the control signal on the sensor signal, the distortional motion may be generated at the desired pedal positions along the trajectory, preferably at predetermined pedal positions. A predetermined and repeatable profile of distortion events along the trajectory may thus be generated. The distortion device may be arranged for controlling the intensity of the repeated distortional motion so that, during the repeated motion of the pedal along the trajectory, the intensity is larger in the extending trajectory portion than in the retracting trajectory portion.

[0123] Generally, the control signal may be generated based on controlling software running on a control computer included by the controller 80A. The controller 80A may thus be arranged for controlling the distortion events 20. By means of the controlling software and the control computer, generating the distortion events may be predetermined. Optionally, the distortion device is provided with a user interface for receiving input from a user. Such input may include information on, or related to, controlling of the distortional motion. The information may e.g. relate to a number, or a maximum number, of distortion events optionally per time period, a preferred position and/or direction of the distortional motion, an intensity threshold, a force threshold, an upper trajectory time limit and/or a lower trajectory time limit, a number of distortion events per pedal and/or per pedal revolution, and/or other information that may determine the distortional motion.

[0124] Preferably, the sensor signal generated by the sensor 8oB is also indicative for a trajectory time needed for the pedal 12 to move once along the trajectory 14. The controller may be arranged for averaging the trajectory time, e.g. over the last three revolutions of the pedal. The controller 80A may be arranged for controlling the intensity of the distortional motion so that the intensity is below a, preferably predetermined, intensity threshold when the trajectory time is above a, preferably predetermined, upper trajectory time limit. An upper trajectory time may e.g. be approximately 1 second, which corresponds to approximately 60 rotations per minute. Such a high trajectory time may e.g. occur if a user want to takes a rest, stops at a traffic light, is considering other traffic, or stops pedalling or reduces pedalling cadence for another reason. In such situations, distortional motion can be undesired.

[0125] Additionally, or alternatively, the controller 80A is arranged for controlling the intensity of the distortional motion so that the intensity is below a, preferably predetermined, intensity threshold when the trajectory time is below a, preferably predetermined, upper trajectory time limit. Such a low trajectory time may e.g. occur when the user has a high speed, when a resistance to pedalling suddenly drops, when the user makes an error in changing to another gear, etc. In such situations, distortional motion can be undesired. The controller may e.g. be arranged for controlling the intensity of the distortional motion so that the intensity is below 10% of its maximum value or is approximately zero, when the trajectory time is above the upper trajectory time limit and/or is below the lower trajectory time limit.

[0126] Lowering the intensity of the distortional motion, e.g. temporarily changing the distortional motion, when the trajectory time is above the upper limit or is below the lower limit, can improve safety for the user. Distortional motion in situations of relatively low cadence or relatively high cadence may be undesired. The user may be safer e.g. in situations of cornering, stationary starts, stopping, fast downhills, wrong gear selection causing high or low pedal rotations per minute, etc. When a rider moves the pedal against the rotational direction 18 of the pedal, e.g. reverses the crank arm in order to brace for cornering, this may be regarded by the controller as a zero or negative trajectory time, being below said lower threshold. Preferably, the controller is arranged for controlling the intensity of the distortional motion so that the intensity is below the predetermined threshold for a predetermined period of time, e.g. at least a minute, at least three minutes or at least five minutes.

[0127] The battery 8oD, or another energy source, may be electrically connected to one or more actuators of the distortion device. The battery may be arranged for generating electricity used by the one or more actuators for generating the distortional motion. The battery may also be connected to the controller 8oA. Alternatively, the controller may have an additional battery apart from the battery 8oA. Optionally, the battery 8oA is, partly or completely, contained within the crank cavity.

[0128] Figures 7A and 7B show, in different perspective views, another embodiment of a crank 16 according to the present disclosure. The crank 16 is provided with a pedal 12 having a pedal axle 70. Figure 7C shows the crank 16 in a bottom view. Figure 7D shows a side of the crank 16 that, when mounted to the exercise device, faces away from a frame of the exercise device. The crank 16 may include a crank body 30, a crankshaft 34, a pedal mounting part 40 received by the crank, and a slot 32 in the crank body 30. The slot 32 may have a shape that is substantially longitudinal, optionally slightly curved, and optionally with rounded corners and/or one or more rounded slot ends 33A, 33B. The corners and/or slot ends preferably match a circumference of the movable pedal mounting part 40. A length L_1 of the crank body 30 may be in a range from 200 to 250 mm. A span width W_1 of the crank body 30 may be in a range from 20 to 80 mm, preferably in a range from 30 to 60 mm. A distance L_2 (indicated in figure 7D) between a center of the crankshaft 34 and a center of the pedal mounting part 40, may be in a range from 160 to 175 mm. A maximum pedal displacement d_{max} as a result of the distortional motion (indicated in figure 7D) may be in a range between 4 mm and 25 mm, preferably between 4 mm and 15 mm. The maximum pedal displacement may be reached in a time period that is between 10 ms and 50 ms, preferably between 15 ms and 30 ms. A height V of the crank body 30 may be in a range from 30 to 90 mm. The height V of the crank may vary strongly. The crank may e.g. be, partly or completely, disc-shaped. Such a disc may be hollow, thus providing the cavity.

[0129] Figures 7E-7H illustrate parts of the distortion device that may be contained in the crank cavity 44 of the crank body 30. The crank body may have an inner crank body part 30A. In the embodiment of figures 7A-7H, the crank 16 is provided with a single actuator 80C. The actuator may be a unidirectional actuator, arranged for actuation along, e.g. back and forth, substantially one direction. Alternatively, the actuator may be a multidirectional actuator, arranged for establishing motion in a plurality of directions that are inclined with respect to each other. The actuator 80C is provided in the crank cavity 44. The actuator 80C may be an electromagnetic actuator. The actuator 80C may include a coil 82 that works together with a core 84. The actuator 80C may e.g. include a ferromagnetic core. The coil may be fixed to the crank body, e.g. to an inner surface of the crank body's cavity 44. The core may be, at least partly, received in an inner space formed by the windings so that it moves as a result of an electromagnetic field caused by current in the windings. Windings of the core may e.g. be non-circular such as rectangular (i.e. follow a substantially rectangular path around said inner space) or may be non-rectangular such as circular of elliptical. The windings of the core may be shaped to optimize dimensions of the cavity 44 and/or optimize the crank body 30 and the force that can be generated by the actuator 80C. The windings may be shaped to match a shape of the inner surface of the crank body's cavity 44.

[0130] The distortion device may include an actuation arm 42. Figures 7D-7H illustrate that a longitudinal direction of the actuation arm and a longitudinal direction of the crank body may be substantially aligned with each other. The actuation arm may be formed, partly or completely, by the core of the actuator 80C. In the embodiment shown in figures 7A-7H, the actuation arm actuating part 91 may be formed by the core 84. As shown in figure 7G, the actuation arm 42 may extend along the longitudinal direction 41 of the crank body 30. The actuation arm 42 may include a first pivotable coupling 85A, and optionally may include a second pivotable coupling 85B. The pivotable couplings 85A, 85B can be translated with respect to the crank body. The actuation arm 42 may contain a link element 98 that has a pivotable coupling 85A, 85B at both of its ends to connect to other parts of the actuation arm, such as the actuating part 91. The actuation arm may be pivotably (or, in other words, rotatably) connected to the crank body 30, by means of the pivotable connection 60. The pivotable couplings 85A, 85B, and in this embodiment also the pivotable connection 60, are arranged to mechanically couple the actuation arm 42 to the pedal 12 when mounted in the pedal mounting part 40. The pivotable connection 60 of the actuation arm 42 (or, in other words, a fulcrum actuation arm connection) may provide leverage so to increase the amplitude and/or acceleration of an actuation arm coupling part 87 near the pedal mounting part (compared to the amplitude of the core of the actuator). The other way round, the pivotable connection 60 may also be positioned to decrease the amplitude and/or acceleration near the actuation arm coupling part 87.

[0131] Thus, more in general, the actuation arm 42 may include an actuation arm coupling part 87 that may be arranged to mechanically couple to the pedal mounting part and pedal, may include an actuation arm actuating part 91 that may be arranged to be directly actuated by the actuator or another part of the distortion device (such as a cam), and may include a link element 98 to connect both parts to each other. The link element 98 may have a pivotable coupling at both ends to connect to and in between the actuation arm coupling part 87 and the actuation arm actuating part 91. The link element 98 or the actuation arm coupling part 87 may be pivotably connected to the crank body 30, by means of the pivotable connection 60. By means of the pivotable mechanical couplings 85A, 85B and the pivotable mechanical connection 60, the distortional motion of the pedal relative to the crank body may be directed transverse to the longitudinal direction of the crank body. As a result, the pedal mounting part 40 may be distorted from a base position (illustrated in figure 7G) to a maximally distorted position (illustrated in figure 7H).

[0132] Figures 8A and 8B show, in mutually different perspective views, a further embodiment of a crank 16 according to the present disclosure. Figures 8A and 8B show the crank 16 having received a pedal mounting part 40, and having a slot 32 and a crank body 30. The pedal is provided with a pedal axle 70. The pedal may be mounted to the pedal mounting part by means of the pedal axle 70. The crank 16 may be provided with the pedal 12. Figure 8C shows the crank 16 in a top view, indicating the span width W_1 of the crank body 30 that may e.g. be in a range from 30 to 80 mm. Figure 8D shows a side of the crank 16 that, when mounted to the exercise device, faces away from a frame of the exercise device. A distance L_2 between a center of the crankshaft 34 and a center of the pedal mounting part 40, may e.g. be in a range from 160 to 175 mm. The slot 32 shown in figures 8A-8D may have a shape that is substantially diamond-shaped, optionally with rounded corners that preferably match a circumference of the movable pedal mounting part 40. A base angle γ of the diamond-shaped slot may be in a range from 30 to 120 degrees. A maximum pedal displacement d_{max} may be in a range from 4 to 25 mm, preferably 4 to 15 mm. Other arc-shaped slots are possible as well. The slot 32 may e.g. have a regularly curved top connecting the sides that define the base angle, so that a distance between the curved top and the base of the base angle γ is similar for all points on the curved top.

[0133] As shown in figures 8E-8H, the crank 16 may receive two actuators 80C. The actuators 80C are received in the crank cavity 44. The actuator 80C may be an electromagnetic actuator. The actuator 80C may include a coil that works together with a core 84. The actuator 80C may e.g. include a ferromagnetic core 84. The windings of the coil around the core may e.g. be circular, elliptical or rectangular (rectangular windings are shown in figure 8E), in order to optimize dimensions of the crank cavity 44. Non-circular, such as elliptical or rectangular, coil windings can limit a body width W_2 (indicated in figure 8C) of the crank body 30. Thus, a coil having windings following an elongated, i.e. non-circular, path, may be beneficial for crank design.

[0134] The actuators 80C are arranged to mechanically couple to the pedal for generating the distortional motion, in this embodiment via an impact coupling. The impact coupling leads, in use, to transfer of momentum. Thus, in use, the actuators 80C may generate an impact coupled movement of the pedal mounting part 40 and the pedal 12. Part of the actuators 80C, e.g. the coil 82 of the actuators 80C, may be fixed to an inner side 86 of the crank body. The core may form or be attached to, or the coil may form or be attached to, a coupling element

88 that is arranged to mechanically couple to the pedal 12. In this embodiment, such mechanical coupling can be established by the coil moving the coupling element 88 in contact with the pedal mounting part 40. Thereto, the pedal mounting part 40 may be provided with contact surfaces 90 to which the coupling element 88 may mechanically couple by contacting the contact surfaces 90 and applying a force to the contact surfaces 90.

[0135] As a result of the coupling elements 88 applying a force on the contact surfaces 90, the pedal mounting part 40 may move through the slot 32. If the pedal is mounted to the pedal mounting part 40, the pedal may also move. Thus, the actuator may be arranged to mechanically couple to the pedal for generating the distortional motion of the pedal 12. Figures 8G and 8H illustrate the distortional motion, i.e. pedal displacement d. Figure 8G shows the pedal mounting part 40 translated through the slot as a result of one of the actuators. Figure 8H shows the pedal mounting part 40 translated through the slot as a result of both actuators. In figure 8H, the pedal mounting part is in a distorted position, in this figure at a top position in the slot 32.

[0136] The controller 80A may be positioned in the crank cavity 44, or alternatively outside the crank cavity 44, e.g. attached to a frame of an exercise device. A slip ring 122 may be provided in the crank to enable electrical contact between electrical components, such as an actuator, an energy source such as a battery, a sensor, and/or a controller, that move with the crank, e.g. are positioned in or on the crank, and electrical components that move with the frame, e.g. are positioned in or on the frame. The controller 8oD may be communicatively connected to the two actuators 8oC. The controller may e.g. be connected to the actuators via the slip ring. The control signal generated by the controller may be arranged for controlling the two actuators 8oC. The two actuators 8oC may be positioned for generating components of the distortional motion of the pedal in different actuation directions 92A, 92B that are inclined relative to each other (see figures 8F and 8G). In this embodiment, both actuation directions may be transverse relative to each other, e.g. may be substantially perpendicular to each other. However, other angular offsets are possible as well.

[0137] The combined use of two actuators enables moving the pedal relative to the crank body in a plurality of directions along a plurality of distortion paths. Thus, the control signal may be arranged for varying a direction and path of the distortional motion relative to the crank body. This may enable optimizing the direction and path of the distortional motion at various pedal positions α along the trajectory 14. Thus, the distortion device may be arranged to control a direction of the distortional motion dependent on the position of the pedal along the trajectory and/or dependent on a force exerted on the pedal along the trajectory, so that the direction varies, preferably repeatedly, along the trajectory.

[0138] In the embodiment of figure 8A-8H, the two actuators are arranged to mechanically couple to the pedal. They are also arranged to allow motion of the pedal caused by another one of the at least two actuators. This may e.g. be achieved by enabling sliding contact between the coupling elements 88 and the contact surfaces 90. The coupling elements 88 and the contact surfaces may e.g. be greased and made of a durable, non-brittle, and smooth material, e.g. a metallic material. Additionally, or alternatively, as illustrated in figure 8F, the two actuators may be positioned at a distance Z from the pedal 12 that enables mechanically coupling to the pedal for moving the pedal in one of the different directions 92A and for allowing, in another one 92B of the different directions, motion of the pedal relative to the the at least one of the at least two actuators. Positioning at the distance Z may also enable a larger impact force on the contact surfaces 90.

[0139] In the embodiment of figures 8A-8H, the pedal 12 may be mechanically coupled to a counteracting element 94, e.g. a compressible and resilient element, positioned for counteracting the movement of the coil 82 in said one of the different directions. The counteracting element may be arranged to bring the pedal 12 and the pedal mounting part 40 back to the base position, as indicated in figure 8D. The counteracting element may be compressible. The counteracting element 94 may include e.g. an elastic spring or another elastic element. Alternatively, or additionally, the counteracting element may include a magnet and/or a dampers, in order to move the pedal mounting part and/or pedal back to the base position. In an embodiment, the coil is preloaded, e.g. mechanically preloaded by means of a spring, so that the distortional motion can be enhanced by means of a force generated by the spring. Preferably, the counteracting element is arranged for restoring the preload. The controller may be arranged to apply a force to counter the preload, as to keep and/or bring back the pedal in its base position. The distortion device may be arranged for restoring the preload, e.g. by reversing the movement of the coil by means of the actuation signal in between distortion events.

[0140] Figure 9A shows an exploded view of a crank in a next embodiment according to the invention. Figure 9B shows parts that are also shown in figure 9A. The crank 16 is provided with the pedal 12, having a pedal axle 70. The crank is provided with the slot 32. The pedal axle 70, and preferably also the pedal mounting part 40, may in use extend through the slot 32. The crank 16 includes a crank body 30 that has an inner crank body part 30A. An actuator is provided in the crank cavity 44. The crank 16 may include the crank bolt 39 to attach the crank 16 to the crankshaft. The pedal mounting part 40 is arranged to receive the pedal axle 70.

[0141] Figures 9A and 9B also show two electromagnetic actuators 80C.1 and 80C.2 of the distortion device. More in general, the actuators 80C.1, 80C.2 may be positioned for actuation in similar actuation directions, e.g. actuation directions that are substantially parallel to each other. Part of the actuators 80C.1 and 80C.2, e.g. the coil 82, may be fixed to an inner side 86 of the crank body by means of actuator mounting structures 96. Each of the actuators 80C.1, 80C.2 may be mechanically connected to an actuation arm respectively indicated by reference number 42.1 and 42.2. Each arm may be provided with a pivotable coupling 85. The pivotable coupling 85 may be moveable in translational motion with respect to the crank body 30. Each of the actuation arms 42.1, 42.2 may be mechanically connected to the pedal mounting part 40. This connection may be rotatable (or, in other words, pivotable), as is illustrated in the embodiment of figures 9A and 9B. Such a rotatable connection may e.g. be realised by means of a ring-shaped element 95. Such a ring-shaped element may be provided on each of the actuation arms 42.1, 42.2. A bearing may be provided in the inside of the ring-shaped element 95, in order to enable smooth rotation of the pedal mounting part 40 relative to the ring-shaped elements 95. By means of the ring-shaped elements 95 and the pivotable couplings 85, the actuators are arranged to mechanically couple to the pedal and to allow motion of the pedal caused by the other one of the two actuators. Such a ring-shaped element may also be applied in other embodiments, e.g. embodiments wherein only one actuation arm 42 per crank body 30 is provided.

[0142] The actuators 80C.1, 80C.2 are arranged to mechanically couple to the pedal 12 for generating the distortional motion. As can be seen in figures 9A-9B, part of the actuation arm 42 may extend along the longitudinal direction of the crank body and another part of the actuation arm may be transverse to the longitudinal direction 41 of the crank body. Such may be realised by the pivotable coupling 85. Thus, the pivotable coupling may be arranged to mechanically couple the actuation arm to the pedal in order to realise the distortional motion of the pedal relative to the crank body to be directed transverse to the longitudinal direction of the crank body. The controller 80A depicted in figure 6 may be communicatively connected to the two actuators. The control signal generated by the controller may be arranged for controlling the at least two actuators 80C.1, 80C.2. The actuators are positioned for generating components of the distortional motion of the pedal in different directions. These may be inclined, e.g. transverse, relative to each other, and/or may be opposite relative to each other. The actuation directions 101A, 101B (illustrated in figure 9C) of the actuators positioned in a cavity of one and the same crank may generally also be different from each other. An angle θ between both actuation directions may be at least zero degrees and/or at most 90 degrees.

[0143] Figures 9C, 9D, and 9E illustrate positions of the pedal mounting part 40 and the pedal axle 70 during distortional motion of the pedal. Figure 9C shows the crank 16 without the inner crank body part 30A. The pedal axle 70 and the pedal mounting part 40 (and hence also the pedal) are in the base position. Figure 9D shows the pedal axle 70 and the pedal mounting part 40 in a distorted position, wherein the distortion is directed perpendicular to the longitudinal direction 41 of the crank body 30. Figure 9E shows the pedal axle 70 and the pedal mounting part 40 in another distorted position (an angled position), wherein the distortion is transverse to the longitudinal direction 41 of the crank body 30. The slot 32 may be designed so that, more in general, a maximum distortion d_{max} in all directions is substantially equal, e.g. in a range from 3 mm to 25 mm. In the example of figure 9E, the distortion is directed partly along the longitudinal crank direction 41 and partly perpendicular to the longitudinal crank direction 41 (the latter component of the distortion being larger).

[0144] Figure 10A shows, in an exploded view, a yet further embodiment of a crank according to the invention. The crank 16 may be included by an exercise device according to the invention that includes a distortion device that is arranged to mechanically couple to the pedal for generating repeated distortional motion of the pedal. Figures 10B and 10C show a perspective view of parts that are also shown in figure 10A. The crank has a crank body 30 that includes an inner crank body part 30A that, in use of the crank, faces a frame of the exercise device. The crank may be provided with a slot 32 in the crank body 30, in this embodiment in the inner crank body part 30A and the outer crank body part 30B. The slot may constrain the distortional motion of the pedal relative to the crank body. Figures 10B and 10C show a perspective view of parts that are also shown in figure 10A. The crank 16 may be provided with a crank bolt 39 for attaching the crank to a crankshaft. A pedal 12 may be provided on the crank 16, e.g. by screwing a pedal axle 70 in a pedal mounting part 40 of the crank 16. The pedal 12 may be arranged for receiving a force exerted on the pedal 12 by a user of the exercise device 2.

[0145] The crank 16 may have a crank cavity 44. Parts of the distortion device may be, partly or completely, provided in the crank cavity 44. In the embodiment of figure 10A, the distortion device includes a first actuator 80C.1 and a second actuator 80C.2. These first and second actuator may be push and pull actuators. A controller of the distortion device may be communicatively connected to the actuators for controlling the intensity of the distortional motion by means of a control signal. The actuators may be provided in the crank cavity 44 and are arranged to mechanically couple to the pedal 12 for generating the distortional motion. The coupling may be realised by a first actuation arm 42.1 and a second actuation arm 42.2. The first actuation arm 42.1 may be mechanically coupled to the first actuator 80C.1. The second actuation arm 42.2 may be coupled to the second actuator 80C.2. Both actuation arms may be different from each other. The actuators 80C.1, 80C.2 are positioned for generating components of the distortional motion of the pedal in different directions that are inclined and/or opposite relative to each other (an angle between the two directions may e.g. be in a range between 30 and 90 degrees). In the embodiment of figures 10A-10G, the actuators are mounted inside the crank. In use, the pedal is translated relative to the crank body as a result of the distortional motion of the pedal generated by means of the actuators.

[0146] Figures 10D, 10E, 10F, and 10G illustrate positions of a pedal mounting part 40 and pedal axle 70 during distortional motion of the pedal. Figure 10D shows the pedal mounting part 40 and the pedal axle 70 in a base position in the slot 32. Figure 10E shows the pedal mounting part 40 and the pedal axle 70 in a first distorted position. Figure 10F shows the pedal mounting part 40 and the pedal axle 70 in a second distorted position, in this example a top position when the pedal position is at an angle α along the trajectory of approximately 90 degrees. Figure 10G shows the pedal mounting part 40 and the pedal axle 70 in a third distorted position. Figures 10E-10G illustrate a maximum distortion d_{max} in different directions. The slot 32 may be designed so that the maximum distortion in all directions is substantially equal. The maximum distortion may e.g. be in a range from 3 to 25 mm. E.g. by means of the slot 32 the crank is arranged to allow, when the pedal is provided on the exercise device and is mechanically coupled to the crank, translational motion of at least part of the pedal relative to the crank body, e.g. between the base position and the first, second, and/or third distorted position.

[0147] In the embodiment of figures 10A-10G, the slot is substantially diamond-shaped, preferably with rounded corners that match a circumference of the pedal mounting part. The pedal mounting part may be round, e.g. may have a substantially circular circumference, at least near the slot 32. The diamond-shaped slot 32, in combination with the two actuators, enables movement of the pedal in directions that are substantially transverse, e.g. perpendicular, to the longitudinal direction of the crank body or may be directed substantially along the longitudinal direction of the crank body. Preferably, the majority of the distortional motion of the pedal relative to the crank body is directed transverse to the longitudinal direction of the crank body (a smallest angle of about 30 degrees (or larger) between both directions may already be considered transverse). In this way, a relatively large portion of the distortional motion can be generated while a force exerted on the pedal is relatively large.

[0148] Figures 10C-10G also show the first and second actuation arms 42.1 and 42.2. Each of the arms has two pivotable couplings 85. Such couplings 85 may be positioned in the actuation arms for translational motion of the couplings with respect to the crank body 30. Thus, each of the arms 42.1, 42.2 may contain a link element 98 that has a pivotable coupling at both ends to connect to other parts of the respective actuation arm. By means of the link element, rotation of the core of the actuator may be prevented. More in general, a larger range of different paths of distortional motion may be enabled by the link element. Each actuation arm 42.1, 42.2 may include an actuation arm coupling part 87, an actuation arm actuating part 91, and a link element 98 mechanically pivotably coupled in between. The link element 98 may comprise two link element parts 99A, 99B that are substantially parallel to each other. End portions of the actuation arm actuating part 91 and/or the actuation arm coupling part 87 may be provided in between the two link element parts. The actuators 80C.1, 80C,2 may be positioned to move the actuating parts 91 of the actuators in substantially parallel directions.

[0149] At least part of the first actuation arm 42.1, here the actuation arm coupling part 87, may be fixedly connected to the pedal mounting part 40, e.g. by connection 100 that may e.g. be a welded connection or a glued connection (indicated in figures 10A and 10B). The second actuation arm 42.1 is slidingly connected to the pedal mounting part 40. Thereto, the second actuation arm may include a sliding element 102, which may surround the pedal mounting part 40 when provided in an inner space 104 of the sliding element 102. In addition to the slot 32, the inner space 104 may also limit the distortional motion of the pedal mounting part 40 and the pedal axle 70. The sliding element 102 may be pivotally connected to the crank, e.g. by slidable pivotable mechanical connection 60A. The slidable pivotal connection 60A may also allow sliding motion of the sliding element 102 relative to the crank body 30. The slidable pivotal connection may be enabled by a pin 59 fixed to the crank body 30 that may rotate and slide through a groove 63 provided in the sliding element 102. The sliding element 102 may form the actuation arm coupling part 87. Thus, more in general, the actuation arm coupling part 87 may be slidingly coupled to the pedal and pedal mounting part.

[0150] It may thus be clear from figures 7A-10G that the distortion device, by means of the controller, the sensor, and the actuators, may be arranged to control an intensity of the distortional motion dependent on the position of the pedal along the trajectory and/or dependent on the force exerted on the pedal along the trajectory. The sensor signal may, in use, contain information on the pedal position along the trajectory and/or on the force exerted on the pedal. The controller may generate the control signal so that the actuators distort the pedal when the pedal is at a certain position along the trajectory and/or when the exerted force is at a certain level. The control signal may be similar for each subsequent revolution, or for each sequence of a plurality of revolutions, of the pedal along the trajectory. As a result of the control, the user may experience similar distortional motion repeatedly at a similar, e.g. the same, pedal position (in case of one distortion event along the trajectory) or at similar pedal positions (in case of a plurality of distortion events along the trajectory). As a result, the intensity repeatedly varies along the trajectory.

[0151] Figure 11A shows a crank 16 in a yet other embodiment according to the present disclosure. Figure 11B shows an exploded view of the crank. The crank is provided with a pedal 12 that is arranged to receive a force exerted by a user of the exercise device. In use, the pedal 12 is mounted to the exercise device, and the pedal is repeatedly moved along the trajectory. The exercise device includes a distortion device that is arranged to mechanically couple to the pedal 12 for generating distortional motion of the pedal. The distortion device is, by means of a cam 50, arranged to control an intensity of the distortional motion dependent on a position of the pedal along the trajectory. Alternatively, or additionally, the distortion device is arranged to control an intensity of the distortional motion dependent on the force exerted on the pedal along the trajectory. As a result, in use, the intensity varies along the trajectory.

[0152] The crank 16 includes a crank body 30 and may receive a pedal mounting part 40 that is arranged for mounting the pedal to the crank 16. The crank may be arranged to allow motion of the pedal mounting part relative to the crank body 30. Thus, the pedal mounting part 40 may be movable with respect to the crank body 30. The crank may be arranged for receiving an actuation arm 42 of the distortion device. The actuation arm 42 may be rigid, e.g. may be made out of one piece and/or may be without pivotable couplings. The actuation arm 42 may be positioned to mechanically couple to the pedal mounting part 40, and hence also to the pedal 12, for generating distortional motion of the pedal 12 and the pedal mounting part 40. The crank body 30 may be provided with a cavity 44 for receiving the actuation arm 42. The distortion device may be arranged to mechanically couple to the pedal by means of the actuation arm for generating repeated distortional motion of the pedal.

[0153] The distortion device may include the cam 50 and a cam follower 52, as illustrated in figures 11B-11E. The cam 50 may define a cam path 54 for the cam follower. The cam and the cam follower may be mounted so that, in use, at least one of the cam and the cam follower rotates with respect to the frame while the pedal moves along the trajectory. In the embodiment of figures 11A-11E, the cam 50 is fixed to a hollow member 38 that is fixed to the frame of the exercise device. The cam follower may be pivotably connected to the crank body 30, by means of pivotable connection 60. Thus, the cam 50 may be fixed relative to the frame while the cam follower 52 rotates while the pedal moves along the trajectory. As a result, the cam follower 52 repeatedly follows the cam path 54, by rotating with respect to the frame. The cam follower may include a cam follower bearing 61, e.g. in the form of a rotatable ring positioned at an end of the cam follower.

[0154] The cam path has a deviation 66 from a circular shape 57, containing a first deviation portion 66A and a second deviation portion 66B, in order to cause the distortional motion as a result of the cam follower following said deviation. The circular shape 57 may be defined relative to the axis of rotation 55 of the cam, said axis of rotation coinciding with the center of the circular shape 57. The deviation 66 is distributed unevenly along the cam path. Each flat planar cross section 53A, 53B through and along an axis of rotation 55 of the cam preferably divides the cam path in two unequal cam path portions, e.g. in two portions of unequal length and/or shape. The first deviation portion 66A may be designed for bringing the cam follower away from an axis of rotation 55 of the cam 50. The second deviation portion 66B may be designed for bringing the cam follower towards the axis of rotation 55 of the cam 50. A first portion 54A of the cam path 54 along the second deviation portion 66B may be less than, e.g. at most 20 % of or at most 10 % of, a second portion 54B of the cam path along the first deviation portion 66A.

[0155] As is illustrated in figures 11C-11E, the first cam path portion 54A may be shaped for regularly bringing the pedal and pedal mounting part to a base position (illustrated in figure 11C). The first cam path portion 54A may, partly or completely, be shaped substantially elliptically, thus defining the first deviation portion 66A. The second cam path portion 54B, which may define the second deviation portion 66B, may be shaped to allow movement of the pedal and pedal mounting part abruptly to a distorted position (illustrated in figure 11D). When allowed by the shape of the cam path, this movement may be actuated by a spring or another resilient, preferably elastic, member 120. The resilient element may be attached to an inner surface of the crank body's cavity 44, e.g. at mounting point 123. Alternatively, or additionally, a spring or another resilient, preferably elastic, member 120 may be incorporated in the pivotable connection 60. The abrupt movement of the pedal and pedal mounting part followed by a relatively slow movement back to the base position, may be convenient for the user. A corresponding distortion event may have a pedal displacement about similar to the third distortion event 20 depicted in figure 2B.

[0156] It may be clear that the resilient member 120 is being loaded during a trajectory portion wherein the cam follower is in contact with the first cam path portion 54A. During this time, the pedal and pedal mounting part are brought back to the base position while the cam follower is moved away from the center or axis of rotation 55 of the cam 50. The stored energy is unloaded after the cam follower has reached the second cam path portion 54B, while the cam follower moves back towards the cam center until it again reaches the first cam path portion 54A. Decreasing a portion of the cam path 54 along the second deviation portion 66B may decrease a duration of a distortion event. This embodiment is, like the embodiment described with reference to figures 5A-5F, in particular suitable for use in a stationary exercise device. The energy needed for loading the resilient member may be experienced as a useful contribution to the resistance needed for exercising.

[0157] Thus, in the embodiments described with reference to figure 5A-5F and 11A-11E, based on the deviations 66 of the cam path and the movement of the cam follower along the cam path, the distortion device is arranged to control an intensity of the distortional motion dependent on the position of the pedal along the trajectory. In use, the intensity repeatedly varies along the trajectory, i.e. varies in a similar way along the trajectory during a plurality of revolutions of the pedal. The position of the pedal along the trajectory corresponds with a certain position of the cam follower along the cam path. Thus, the transition from the first cam portion to the second cam portion may take place at about the same pedal position during each revolution of the pedal. Hence, the distortion event may take place at about the same pedal position along the trajectory.

[0158] In the embodiment of figures 5A-5F, the pedal position at which the distortion event occurs may gradually shift along the trajectory, if a number of teeth of the first gear wheel 62 is different from a number of teeth of the second gear wheel 64. This may be preferred by some users, e.g. to experience a variation in effects of the distortion event. Others however may prefer the distortion event to occur at the same pedal position repeatedly during each one of a sequence of revolutions. The number of teeth of the first gear wheel 62 and the number of teeth of the second gear wheel 64 may be equal. Generally, the teeth number, circumference and other properties of the first and second gear wheel may be designed to optimize torque transfer and/or direction change realised by the gear wheels.

[0159] The exercise device, e.g. the exercise device 2 according to the embodiment of figure 1 or figure 6, may be used in a method of operating the exercise device. Figure 12 schematically illustrates an embodiment of such a method. The exercise device may be provided with a crank as described with reference to figures 5A-5F, figures 7A-7H, figures 8A-8H, figures 9A-9E, figures 10A-10G, and/or figures 11A-11E. Variations of such cranks may also be used. The exercise device may be arranged to be provided with a user support for supporting a user of the exercise device, such as the seating 4 shown in figures 1 and 6. The exercise device may be arranged to be provided with a pedal that is arranged for receiving a force exerted on the pedal by the user of the exercise device.

[0160] In an embodiment, the method includes providing the pedal 12 on the exercise device for allowing repeated motion of the pedal relative to the user support along a trajectory. The trajectory includes an extending trajectory portion wherein the pedal moves away from the user support and includes a retracting trajectory portion wherein the pedal moves towards the user support. Examples of such trajectory portions are described with reference to figures 1B, 3, and 4. The method may further include generating, by means of the distortion device 80 that mechanically couples to the pedal 12, distortional motion of the pedal. The method may include controlling, by means of the distortion device 80, the intensity of the distortional motion so that, during the repeated motion of the pedal 12 along the trajectory, the intensity is larger in the extending trajectory portion than in the retracting trajectory portion.

[0161] The method may further include generating, by means of a sensor included by the distortion device, a sensor signal 110 that is indicative for the force exerted on the pedal and/or is arranged for sensing a position of the pedal along the trajectory. The sensor signal may be indicative for the pedal position, i.e. may generally contain information about an approximate position of the pedal along the trajectory. Optionally, the sensor signal also contains information about a pedal angle that a surface 125 (see figures 6 and 11A) along which the pedal extends, makes with the trajectory (in a two-dimensional side view like in figures 1A and 6, or in a flat planar (e.g. vertical) cross section along a longitudinal direction of the exercise device). The sensor may be arranged to determine the pedal angle, e.g. by means of a part of the sensor that comprises a tilt sensor that is fixed to the pedal. The sensor generating the sensor signal may thus have a connection 112 to the pedal 12. This may be a mechanical connection 112 (e.g. in case said part of the sensor is fixed to the pedal) and/or a communicative connection 112 with the pedal.

[0162] The method may further include generating, by means of an actuator 80C that is included by the distortion device and mechanically couples to the pedal, the distortional motion. Such mechanical coupling to the pedal is schematically expressed by arrow 114. The method may further include receiving, by means of a controller 80A that is included by the distortion device and is communicatively connected to the sensor, the sensor signal 110. The method may further include generating, by means of the controller 80A that is further communicatively connected to the actuator 80C, a control signal 116 that is based on the sensor signal 110. By means of the control signal 116, the intensity of the distortional motion may be controlled. The controller may be arranged for timing the actuation by means of the one or more actuators. The distortion device 80 may include a battery 80D that is used for providing electrical power to the controller 80A, the sensor 80B, and/or the actuator 80C. The power may be provided via electrical connections 115 between the battery 80D on the one hand, and the controller 80A, the sensor 80B, and/or the actuator 80C on the other hand. The exercise device may be a bicycle. The method may include transporting the user by means of the bicycle.

[0163] An embodiment of another use or method according to the present disclosure, relates to exercising by means of an exercise device, e.g. the exercise device described with reference to figure 1 or figure 6. The exercise device may be provided with one or more cranks as described with reference to figures 5A-5F and 7A-11E. One such crank may be provided on the exercise device in case the user is interested primarily in bone strength of one of its legs. Two similar cranks may be provided if the user is interested in the bone strength of both legs. Preferably, as for example shown in figures 1 and 6, the exercise device is provided with cranks having crank bodies whose longitudinal directions are substantially aligned. The exercise device may be provided with a user support and with a pedal for allowing repeated motion of the pedal relative to the user support along a trajectory. The use or method may include, supported on the user support of the exercise device, exercising a force on the pedal of the exercise device. Such force exerted by the user may repeatedly vary along the trajectory.

[0164] The method may further include moving the pedal away from the user support in an extending trajectory portion that is included by the trajectory, and moving the pedal towards the user support in a retracting trajectory portion that is included by the trajectory. During exercising, the user may receive distortional motion of the pedal that is generated by a distortion device that is included by the exercise device. The distortion device mechanically couples to the pedal. The intensity of the distortional motion is controlled by the distortion device to be larger in the extending trajectory portion than in the retracting trajectory portion.

[0165] The embodiments described with reference to figures 1A-12 disclose an exercise device, a crank, and a distortion device, in combination and on itself. More in general, a distortion device 80 (figure 12) is disclosed that is arranged for generating repeated distortional motion of a pedal 12 of an exercise device 2. The distortion device 80 may include a sensor 80B arranged for generating a sensor signal 110 that is indicative for a position of the pedal 12 along a trajectory 14 and/or for a force exerted on the pedal 12. The distortion device 80 may include an actuator 80C and an actuation arm 42 that is arranged to mechanically couple to the pedal 12 for generating the distortional motion. The distortion device 80 may include a controller 80A that may be communicatively connected to the sensor 80B to receive the sensor signal 110 and may be communicatively connected to the actuator 8oC for controlling the intensity of the distortional motion by means of a control signal 114. The controller may be arranged for generating the control signal 114 based on the sensor signal 110.

[0166] Moreover, a crank 16 is disclosed that may receive a pedal mounting part 40 that is arranged for mounting a pedal 12 to the crank 16. The crank 16 is arranged to allow motion of the pedal 12 and pedal mounting part 40 relative to the crank body 30. The crank 16 is further arranged for receiving an actuation arm 42 that may be positioned to mechanically couple to the pedal 12 and the pedal mounting part 40 for generating distortional motion of the pedal 12. The crank 16 may include a crank body 30. The crank body 30 may be provided with a cavity for receiving, at least, the actuation arm 42 or a part thereof. The crank may be provided as such as well as in assembly with a distortion device that includes the actuation arm, the distortion device 80 being arranged to mechanically couple to the pedal by means of the actuation arm 42 for generating repeated distortional motion of the pedal 12.

[0167] The actuation arm may be rigid (like in the embodiments of figures 5A-5F, 8A8H, and 11A-11E). Alternatively, the actuation arm may comprise one or more link elements that are pivotably connected to and in between an actuation arm coupling part and an actuation arm actuating part (like in figure 7A-7H and 10A-10E), or may comprise a pivotable coupling in combination with a rotatable connection between the actuation arm and a pedal mount (like in figures 9A-9E), which rotatable connection is also pivotable. Thus, more in general, there may be two, or more than two, pivotable couplings between the pedal and/or the pedal mounting part on the one hand, and the actuator and/or the actuation arm actuating part on the other hand.

[0168] In a generally applicable embodiment, the distortion device may be provided in the crank cavity. Thus, an energy source, the controller, the sensor and the actuator may preferably be provided in the crank cavity. Alternatively, one or more of the energy source (e.g. a battery), the controller, the sensor and the actuator may be provided in an inner space of the frame, in particular in an inner space of the bracket 36. E.g., the battery may be provided in the inner space of the bracket and the actuator may be provided in the crank cavity 44. The pedal may be one of two pedals. The crank may be one of two cranks. Each crank may be fixed to the crankshaft at opposite ends of the crankshaft. Preferably, each crank has a crank body that is fixed to the crank body of the other crank via the crankshaft. In use, each crank body preferably remains substantially static relative to the other crank body. Each of the two pedals may be connected to one of the cranks. The two cranks may each have a crank cavity provided with a distortion device. Thus, an exercise device provided with two cranks may have two distortion devices. The distortion devices may be communicatively connected. The pedals may be translated as a result of the distortional motion of the pedals generated by means of the two actuators.

[0169] Generally, various types of actuators may be used. The actuator 80C may be a voice coil actuator (VCA), with a moving solenoid coil mass. Alternative, the actuator 80C may be an inverted voice coil actuator, or a moving magnet actuator (MMA), using a moving permanent magnet. The actuator 80C may be provided with a multi-coil arrangement. As illustrated with reference to the figures, the distortional motion of the pedal can be realised via a fixed or rotatable coupling of the actuation arm to the pedal mounting part (and hence to the pedal) (like in figures 5A-5F, 7A-7H, and 9A-11E). Alternatively, the distortional movement of the pedal can be realised by a mechanical coupling of the actuation arm, which may optionally include a coupling element, and the actuator to the pedal (and hence to the pedal mounting part) via an impact coupled movement (like in figures 8A-8H). The latter type of mechanical coupling may be advantageously realised by an actuator design where the core is stationary. E.g., a brittle permanent magnet may be stationary and thus free from impact.

[0170] The crank body may include an aluminium alloy, e.g. may be substantially made of an aluminium alloy. The crank body may also include a carbon fiber material and/or a composite material. Parts of the distortion device provided in the crank cavity may e.g. include steel and/or other materials that combine a high strength with a high durability. In the embodiments illustrated with reference to figures in figures 5A-5F, 7A-7H, and 9A-11E, the pedal moves relative to the crank body. The present disclosure however is not limited to this feature. The disclosure may also relate to embodiments wherein the pedal axle is fixed and stationary with respect to the crank. In such embodiment, the crank may move together with the pedal as a result of the distortional motion.

[0171] Features disclosed in relation to one or more of the embodiment described herein, may be applied in other embodiments as well. For example, features described to a crank that may be used for a user's left leg (like the cranks shown in figures 7A-11E), may be applied to a crank that may be used for a user's right leg (like the crank shown in figures 5A-5F), and vice versa. The invention is not limited to an aspect, embodiment, feature, or example of the present disclosure. All kinematic inversions are considered to be inherently disclosed and to be within the scope of the present disclosure. The use of expressions like "preferably", "more preferably", "in particular", "in a variation", "e.g.", "for example", "may", "can", "could", "embodiment", "aspect" etc. is not intended to limit the invention.

Claims

1. Exercise device that is arranged to be provided with a pedal that is arranged, when provided on the exercise device, for receiving a force exerted by a user of the exercise device and for being repeatedly moved by the user along a trajectory so that a position of the pedal repeatedly varies along the trajectory, wherein the exercise device includes a distortion device that is arranged to mechanically couple to the pedal for generating repeated distortional motion of the pedal, wherein the distortion device is arranged to control an intensity and/or direction of the distortional motion dependent on the position of the pedal along the trajectory and/or dependent on the force exerted on the pedal along the trajectory, so that also the intensity and/or direction varies along the trajectory.

2. Exercise device according to claim 1, further arranged to be provided with a user support for supporting a user of the exercise device, wherein the trajectory includes an extending trajectory portion wherein the pedal moves away from the user support and includes a retracting trajectory portion wherein the pedal moves towards the user support, wherein the distortion device is arranged for controlling the intensity of the repeated distortional motion so that, during the repeated movement of the pedal along the trajectory, the intensity is larger in the extending trajectory portion than in the retracting trajectory portion.

3. Exercise device according to claim 1 or 2, including a rotatable crankshaft and a crank that includes a crank body and is fixed to the crankshaft, wherein the pedal, when provided on the exercise device, is mechanically coupled to the crank to allow rotational motion of at least part of the pedal relative to the crank body, the pedal thus being provided on the exercise device to be repeatedly rotated by the user along the trajectory.

4. Exercise device according to claim 3, wherein the crank is arranged to allow, when the pedal is provided on the exercise device and is mechanically coupled to the crank, translational motion of at least part of the pedal relative to the crank body, wherein the crank body extends in a longitudinal direction of the crank body and wherein a majority of the distortional motion of the pedal relative to the crank body is directed transverse to the longitudinal direction of the crank body.

5. Exercise device according to claim 3 or 4, wherein the crank is provided with a slot that is arranged to allow and/or constrain the distortional motion of the pedal relative to the crank body.

6. Exercise device according to one of claims 1-5, wherein the distortion device includes an actuation arm that is arranged to mechanically couple to the pedal for generating the distortional motion, wherein the actuation arm includes a pivotable coupling and/or is pivotally connected to the crank body.

7. Exercise device according to one of claims 1-6, wherein the distortion device includes a sensor arranged for generating a sensor signal that is indicative for the position of the pedal along the trajectory and/or for the force exerted on the pedal, wherein the distortion device includes an actuator that is arranged to mechanically couple to the pedal for generating the distortional motion, and includes a controller that is communicatively connected to the sensor for receiving the sensor signal and is communicatively connected to the actuator for controlling the intensity and/or direction of the distortional motion by means of a control signal, the controller being arranged for generating the control signal based on the sensor signal.

8. Exercise device according to claim 7, wherein the actuator is one of at least two actuators that are arranged to mechanically couple to the pedal for generating the distortional motion, wherein the controller is communicatively connected to the at least two actuators and the control signal is arranged for controlling the at least two actuators, wherein the at least two actuators are positioned for generating components of the distortional motion of the pedal in differ-

ent directions that are inclined and/or opposite relative to each other.

9. Exercise device according to claim 7 or 8, wherein the sensor signal is also indicative for a trajectory time needed for the pedal to move along the trajectory, wherein the controller is arranged for controlling the intensity of the distortional motion so that the intensity is below an intensity threshold when the trajectory time is above an upper trajectory time limit and/or is below a lower trajectory time limit.

10. Exercise device according to at least claim 2 of claims 1-9, wherein the distortional motion includes one or more distortion events along the trajectory, wherein a number of distortion events in the extending trajectory portion is larger than a number of distortion events in the retracting trajectory portion.

11. Distortion device arranged for generating repeated distortional motion of a pedal for an exercise device, the distortion device including a sensor arranged for generating a sensor signal that is indicative for a position of a pedal along a trajectory and/or for a force exerted on the pedal, wherein the distortion device includes an actuator and an actuation arm that is arranged to mechanically couple to the pedal for generating the distortional motion, and includes a controller that is, in use, communicatively connected to the sensor to receive the sensor signal and is, in use, communicatively connected to the actuator for controlling the intensity and/or direction of the distortional motion by means of a control signal, the controller being arranged for generating the control signal based on the sensor signal.

12. Crank including a crank body and including, and/or being arranged to receive, a pedal mounting part that is arranged for mounting a pedal to the crank, the crank being arranged to allow motion of the pedal mounting part relative to the crank body, the crank being further arranged for receiving an actuation arm that is positioned to mechanically couple to the pedal mounting part for generating distortional motion of the pedal and the pedal mounting part, wherein the crank body is provided with a cavity for receiving, at least, the pedal mounting part or a part thereof and the actuation arm or a part thereof.

13. Crank according to claim 12, in assembly with a distortion device that includes the actuation arm, the distortion device being arranged to mechanically couple to the pedal by means of the actuation arm for generating repeated distortional motion of the pedal, wherein the distortion device is a distortion device according to claim 11.

14. Method of operating an exercise device that is arranged to be provided with a pedal that is arranged to receive a force exerted by a user of the exercise device, the method including:

- providing the pedal on the exercise device for allowing repeated movement of the pedal by the user along a trajectory so that a position of the pedal repeatedly varies along the trajectory;
- generating, by means of a distortion device that mechanically couples to the pedal, distortional motion of the pedal; and
- controlling, by means of the distortion device, the intensity and/or direction of the distortional motion dependent on a position of the pedal along the trajectory and/or dependent on the force exerted on the pedal along the trajectory, so that also the intensity and/or direction varies along the trajectory.

15. Use of an exercise device that is provided with a user support and with a pedal for allowing repeated motion of the pedal relative to the user support along a trajectory, the use including:

- supported on the user support of the exercise device, exercising a force on the pedal of the exercise device;
- moving the pedal away from the user support in an extending trajectory portion that is included by the trajectory;
- moving the pedal towards the user support in a retracting trajectory portion that is included by the trajectory;
- receiving distortional motion of the pedal that is generated by a distortion device that is included by the exercise device and that mechanically couples to the pedal, the intensity of the distortional motion being controlled by the distortion device to be larger in the extending trajectory portion than in the retracting trajectory portion.

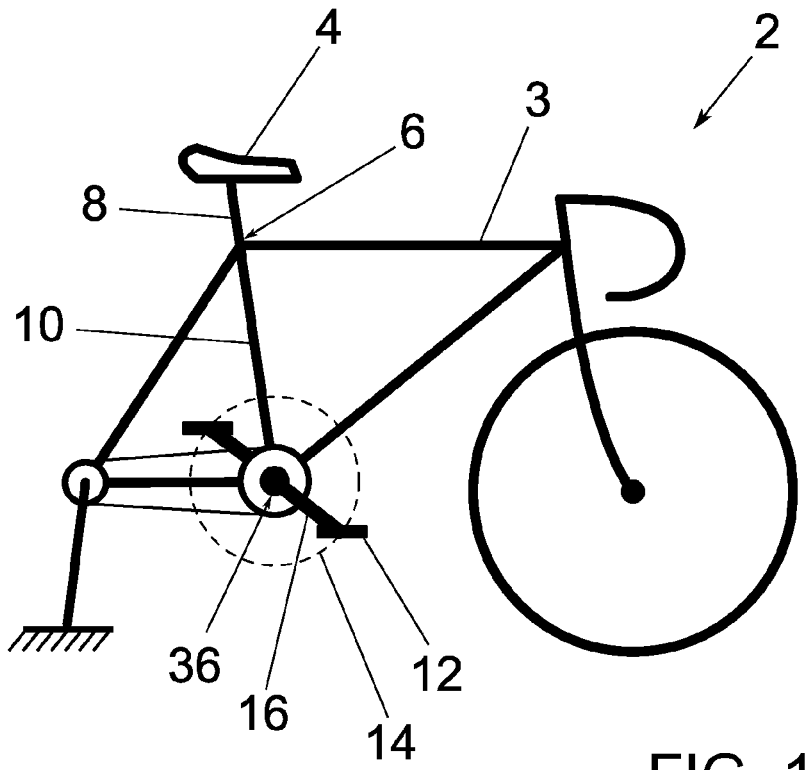


FIG. 1A

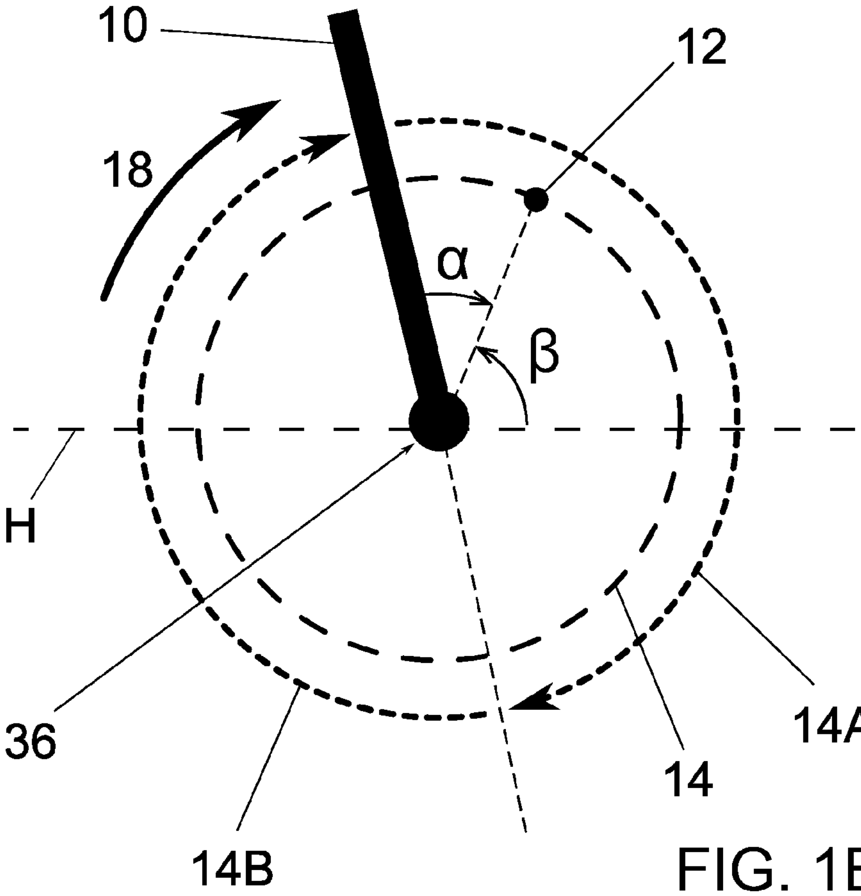


FIG. 1B

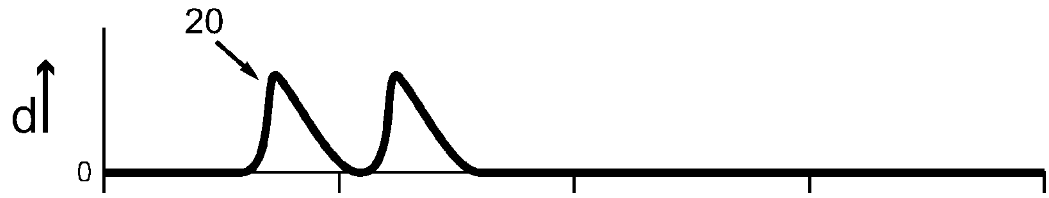


FIG. 2A

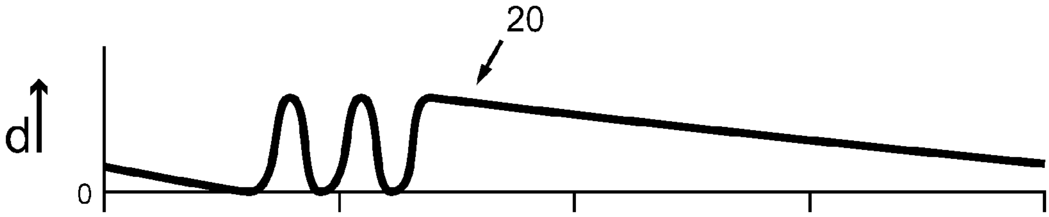


FIG. 2B

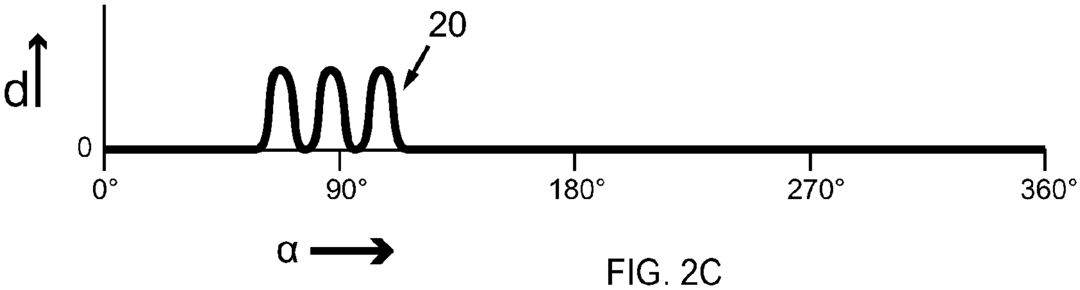


FIG. 2C

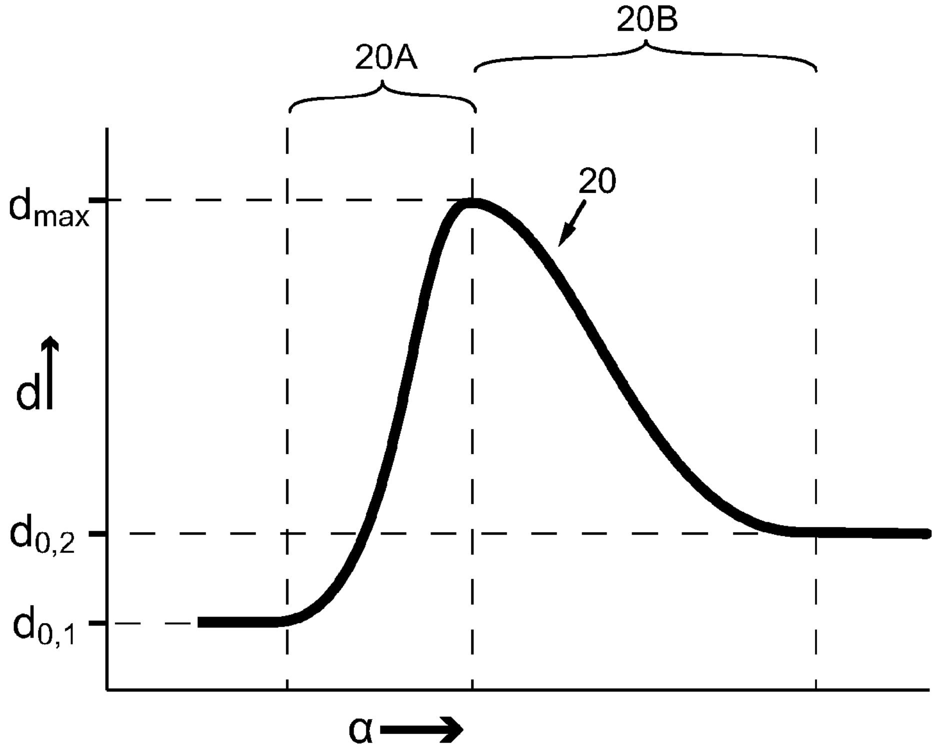


FIG. 3

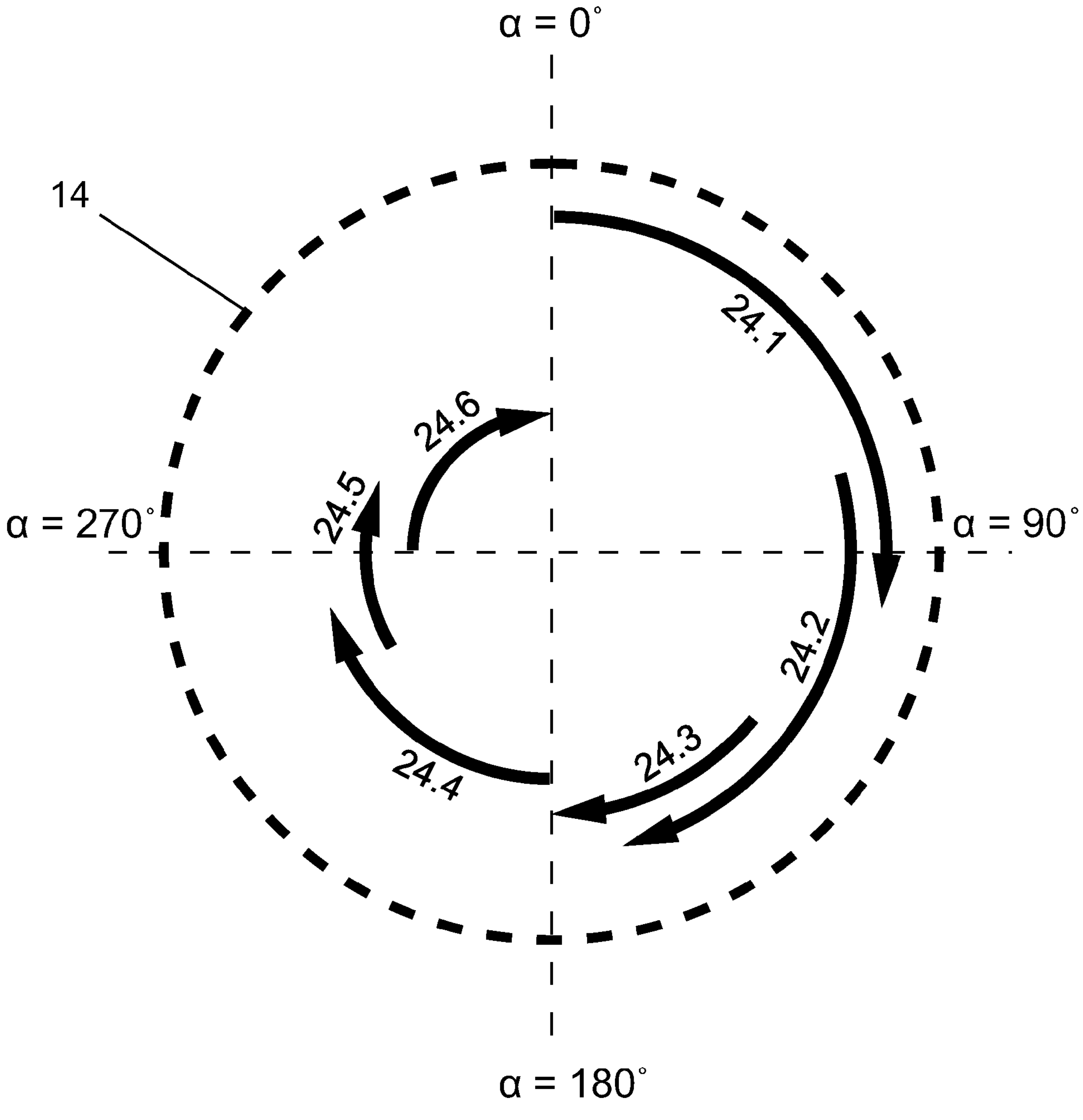


FIG. 4

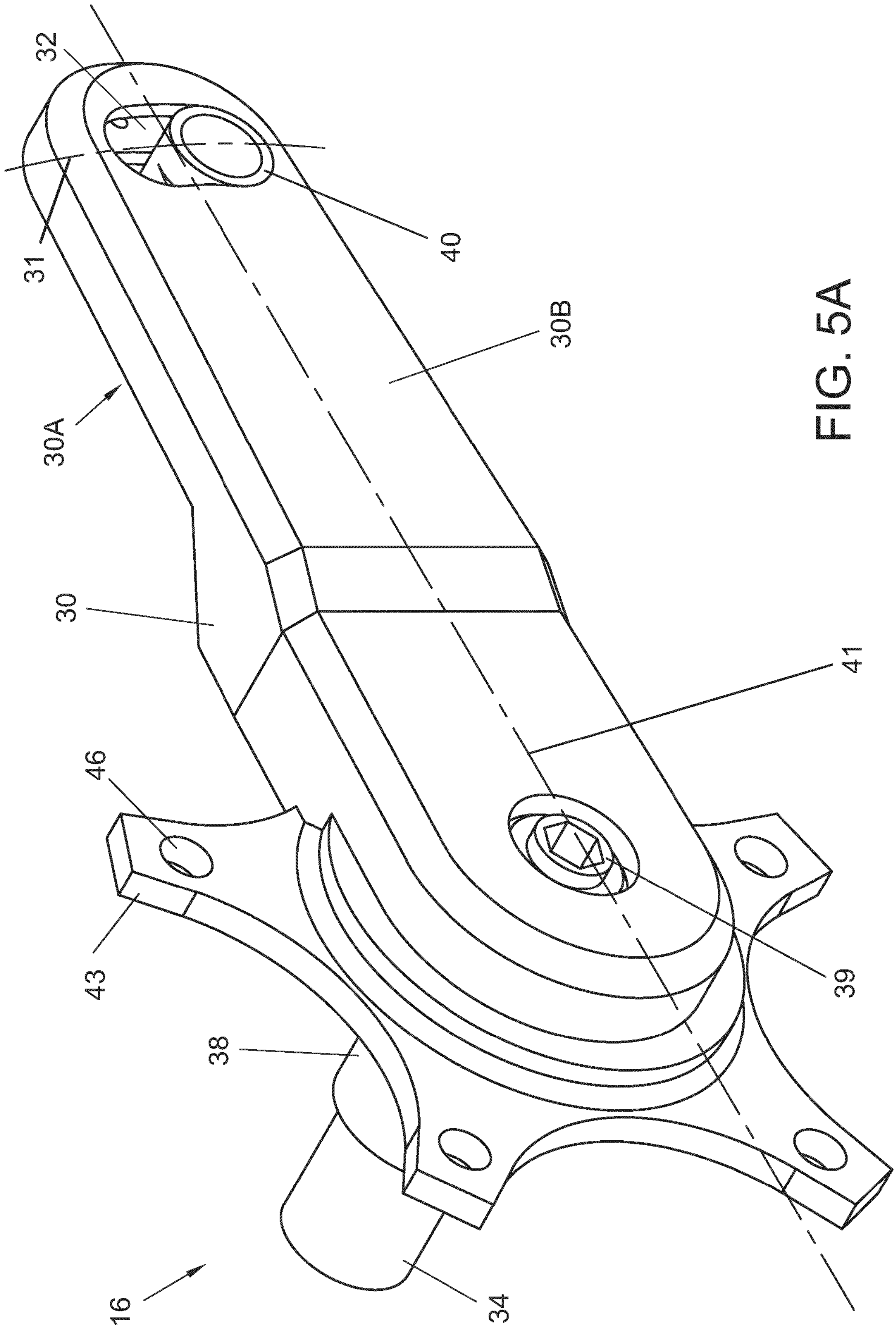


FIG. 5A

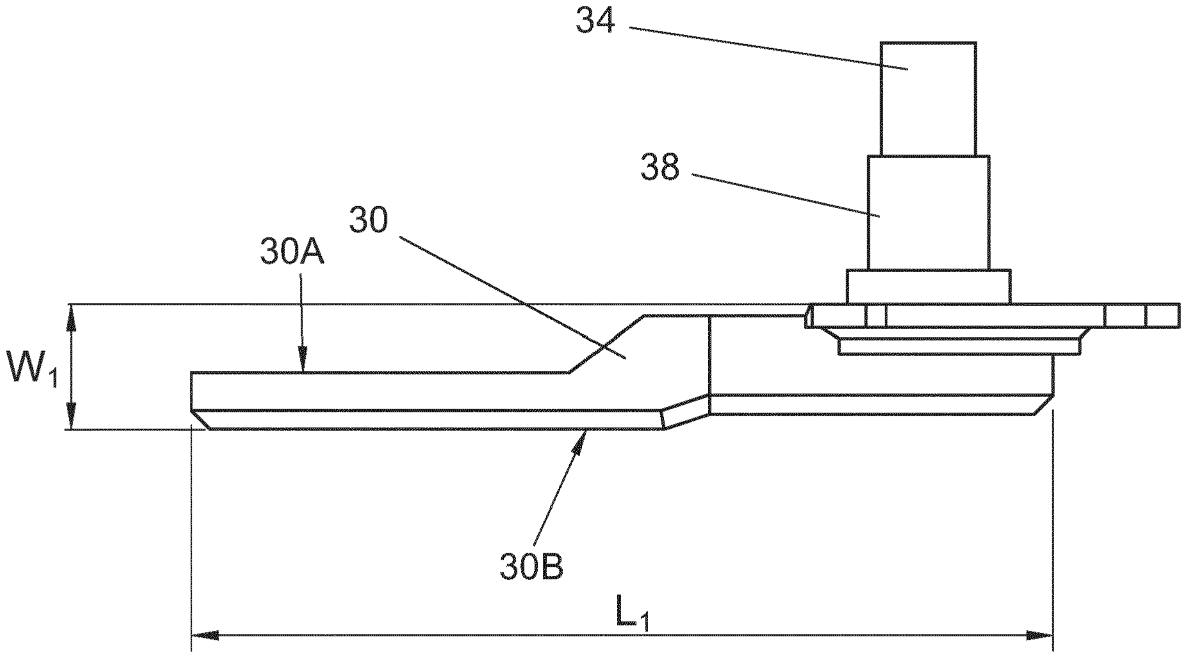


FIG. 5B

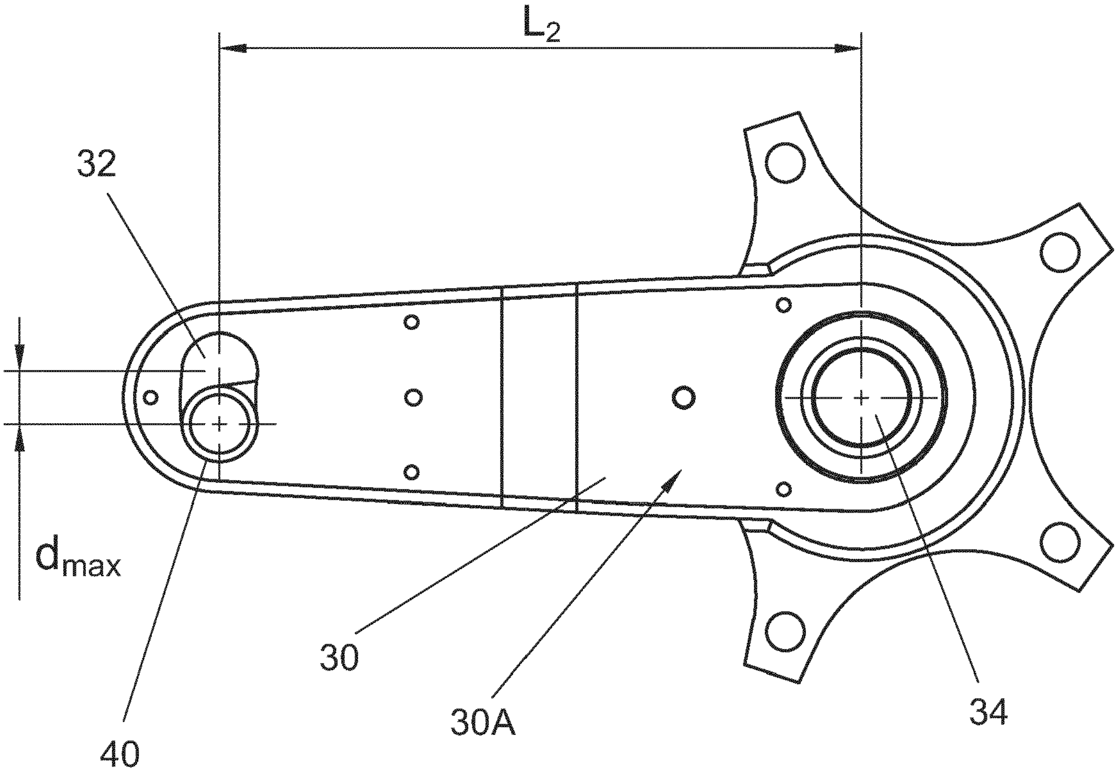


FIG. 5C

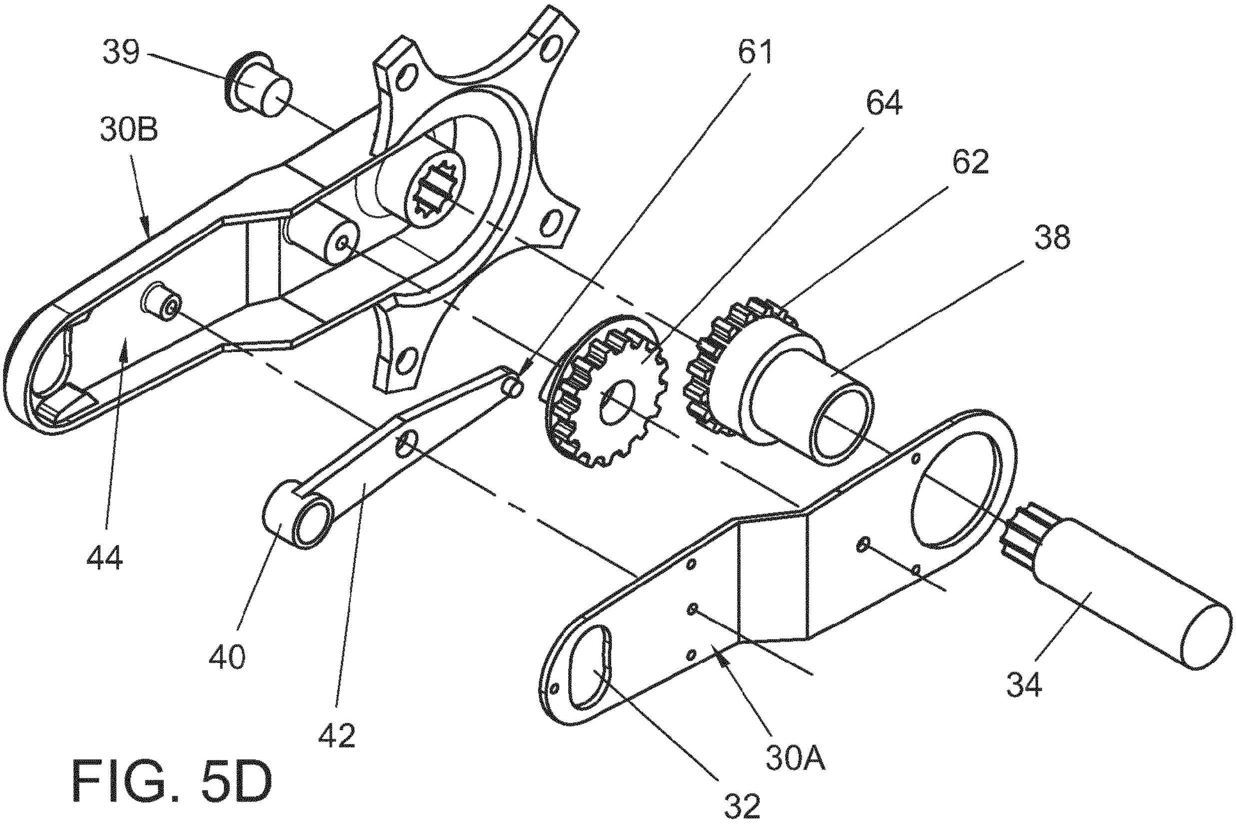


FIG. 5D

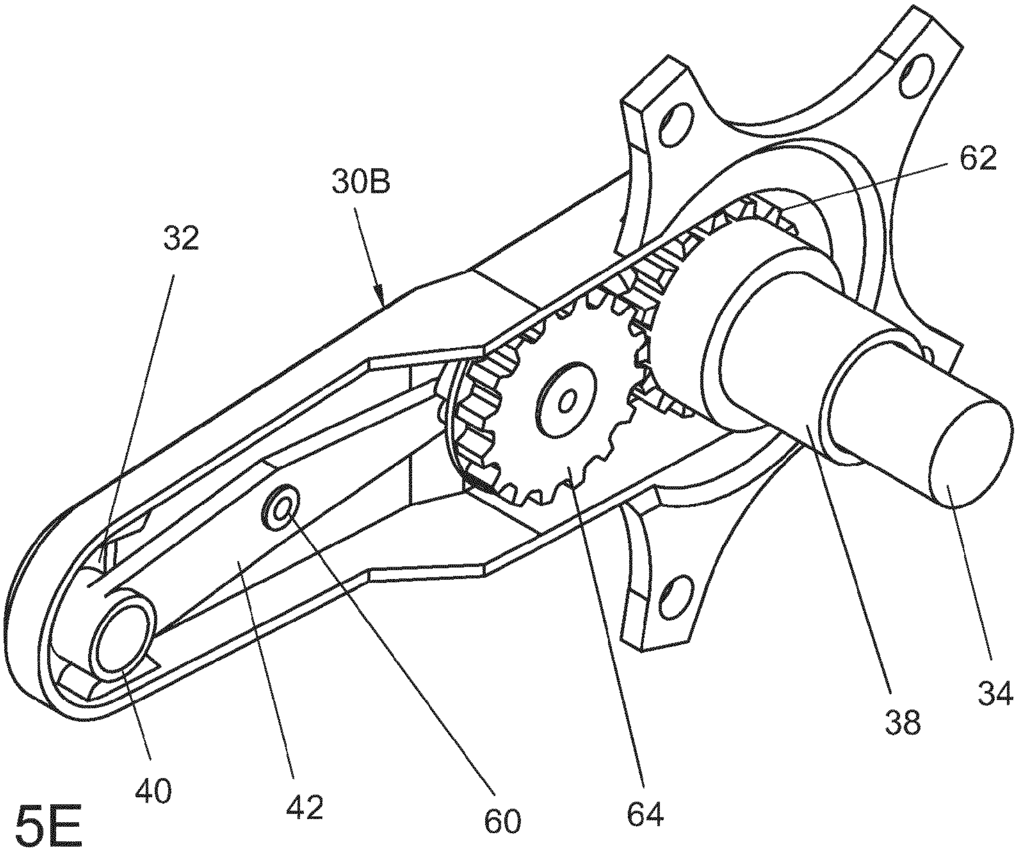


FIG. 5E

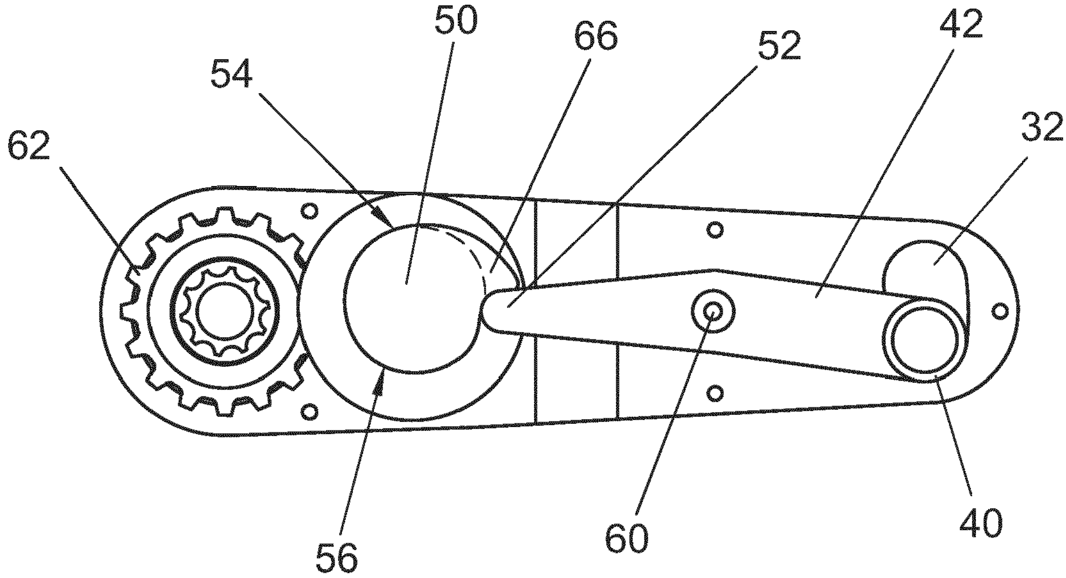


FIG. 5F

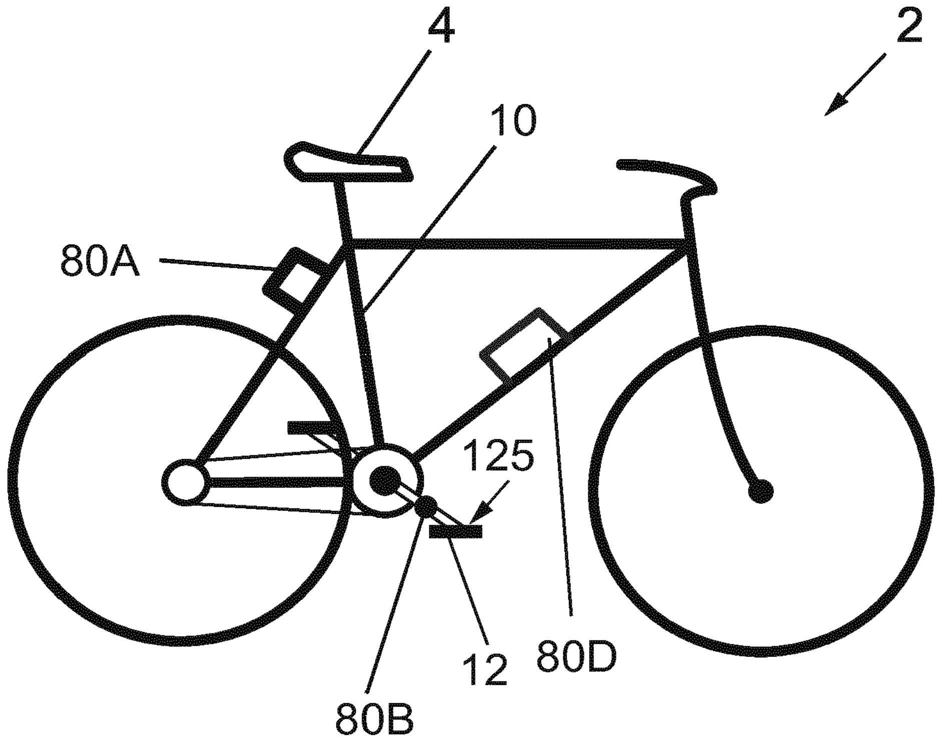


FIG. 6

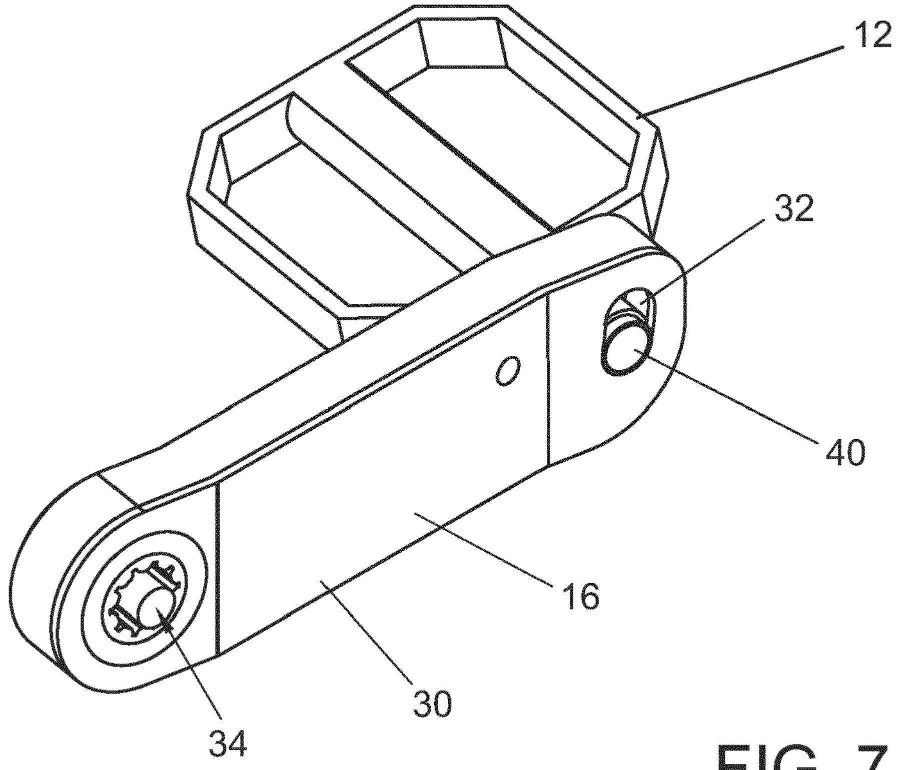


FIG. 7A

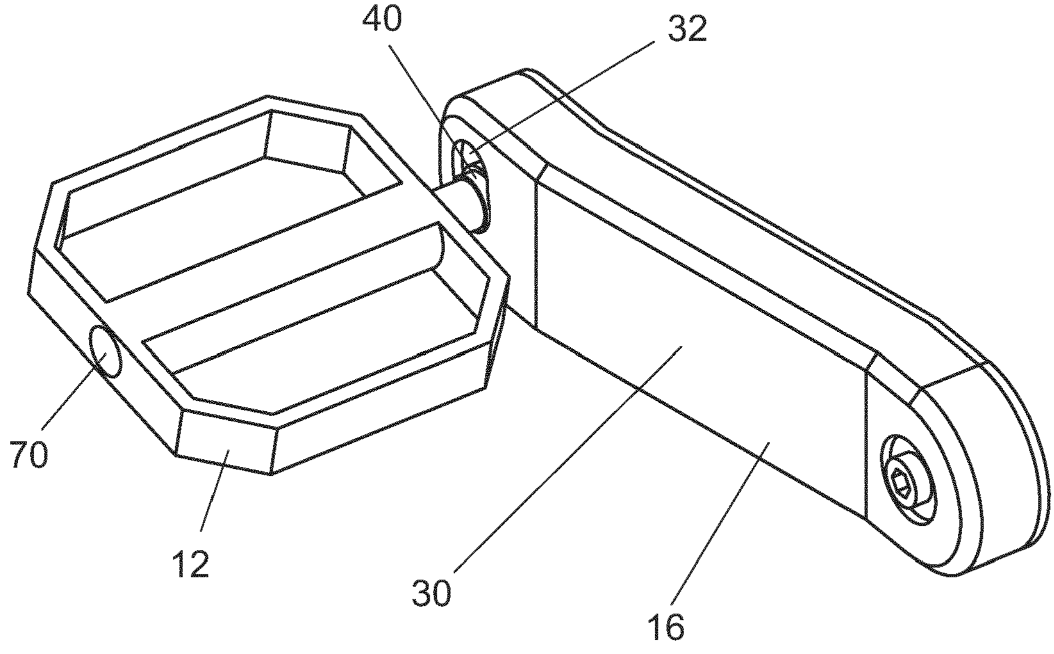


FIG. 7B

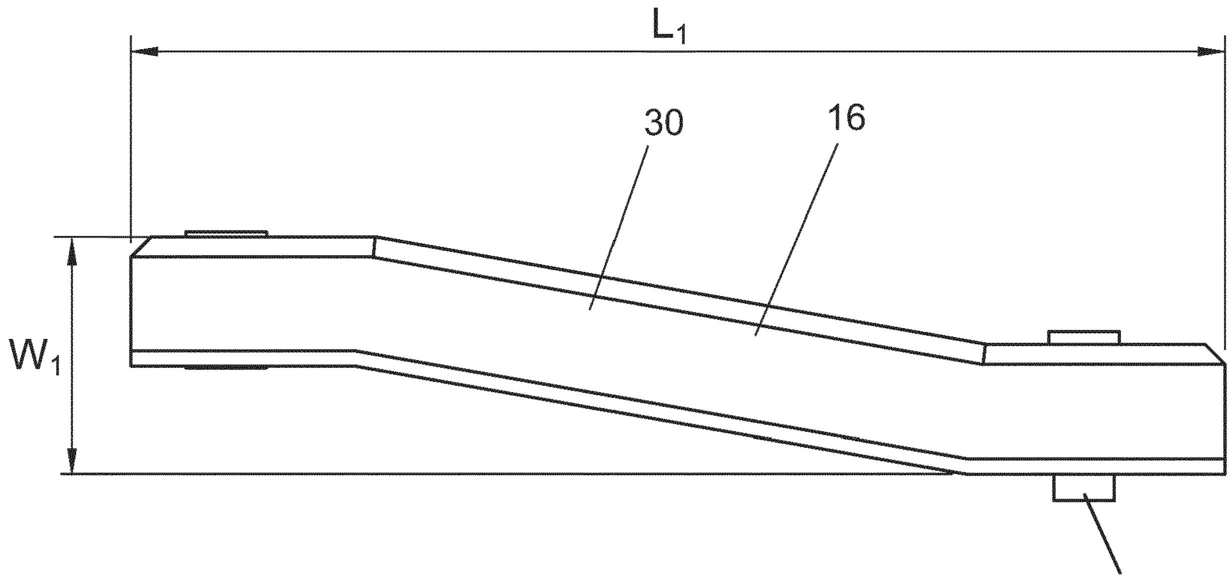


FIG. 7C

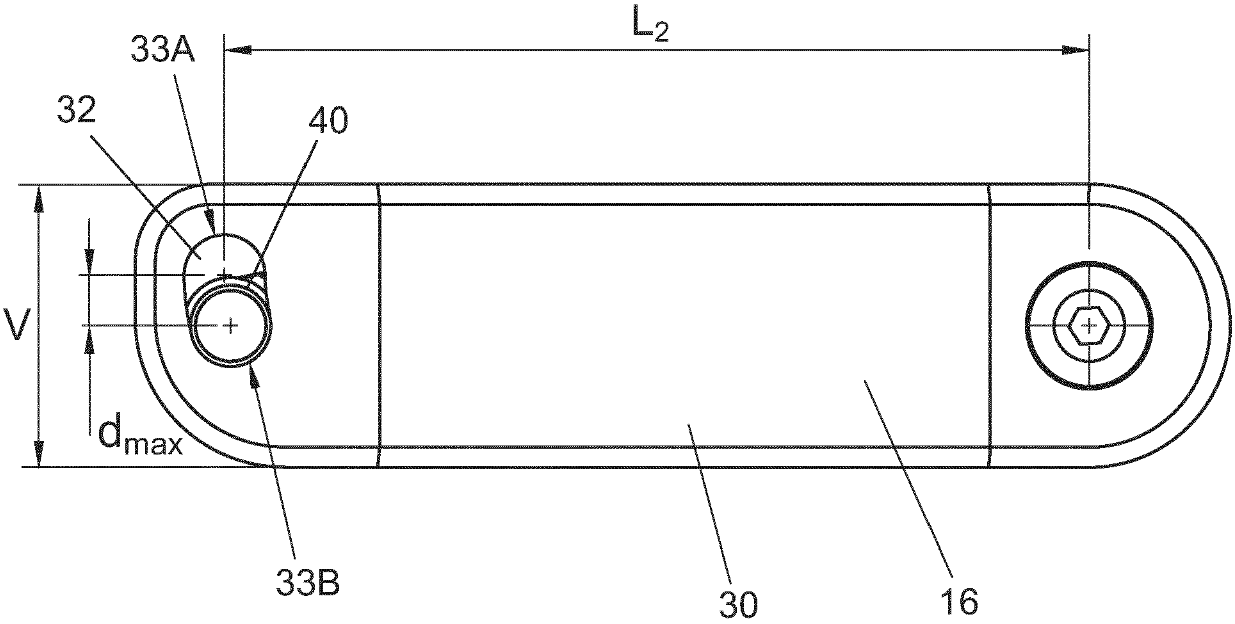


FIG. 7D

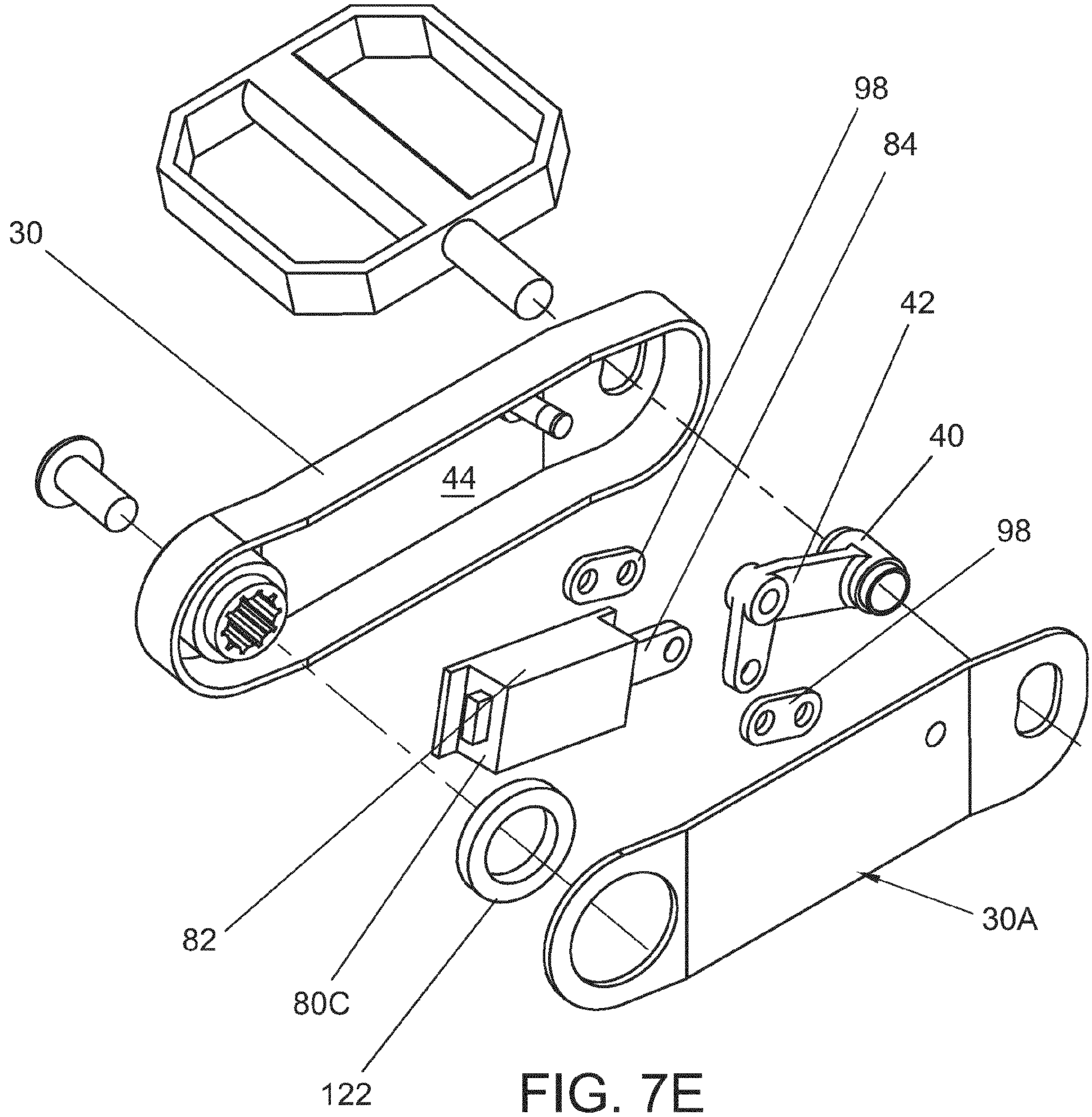


FIG. 7E

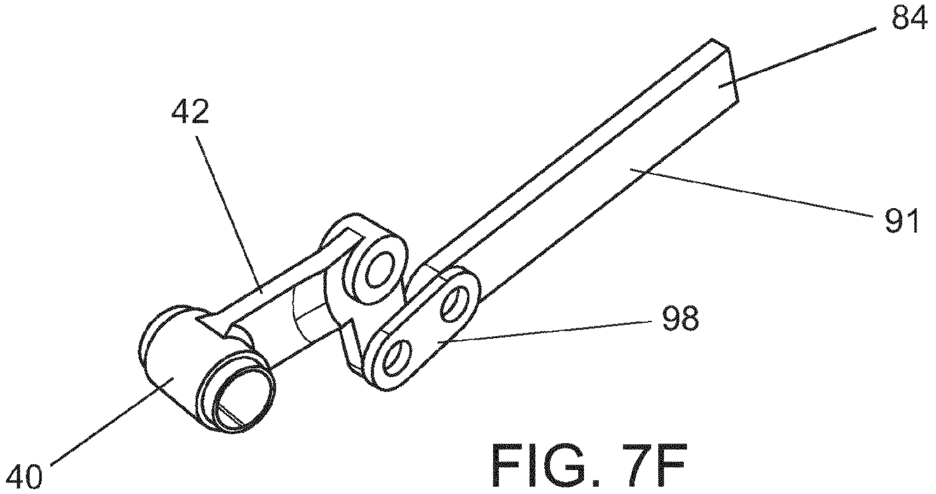


FIG. 7F

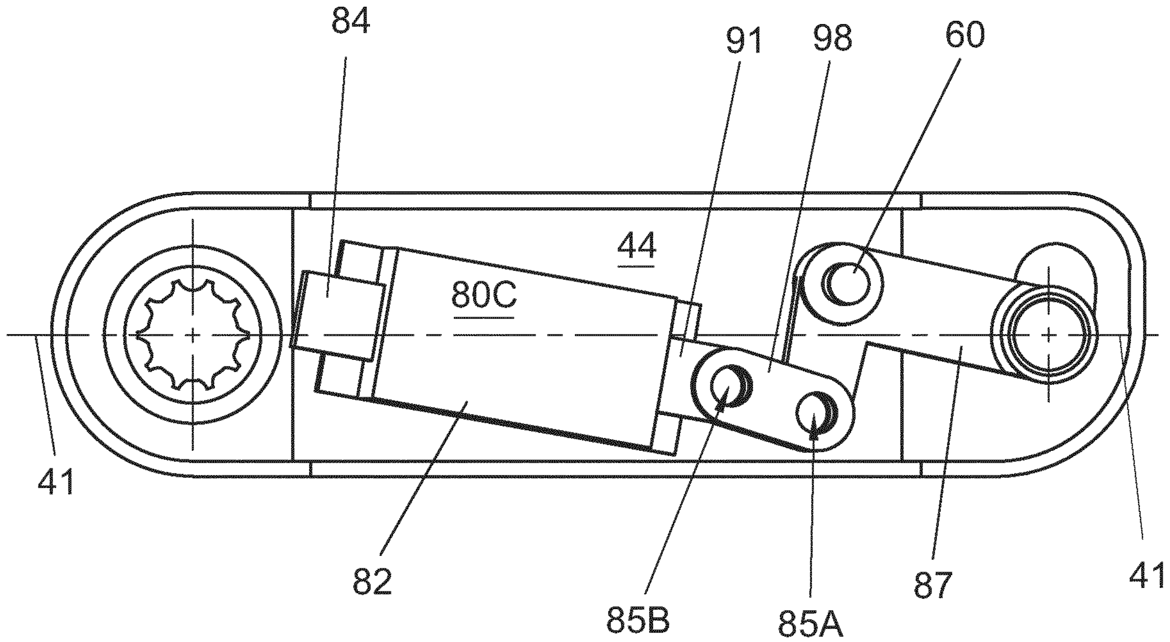
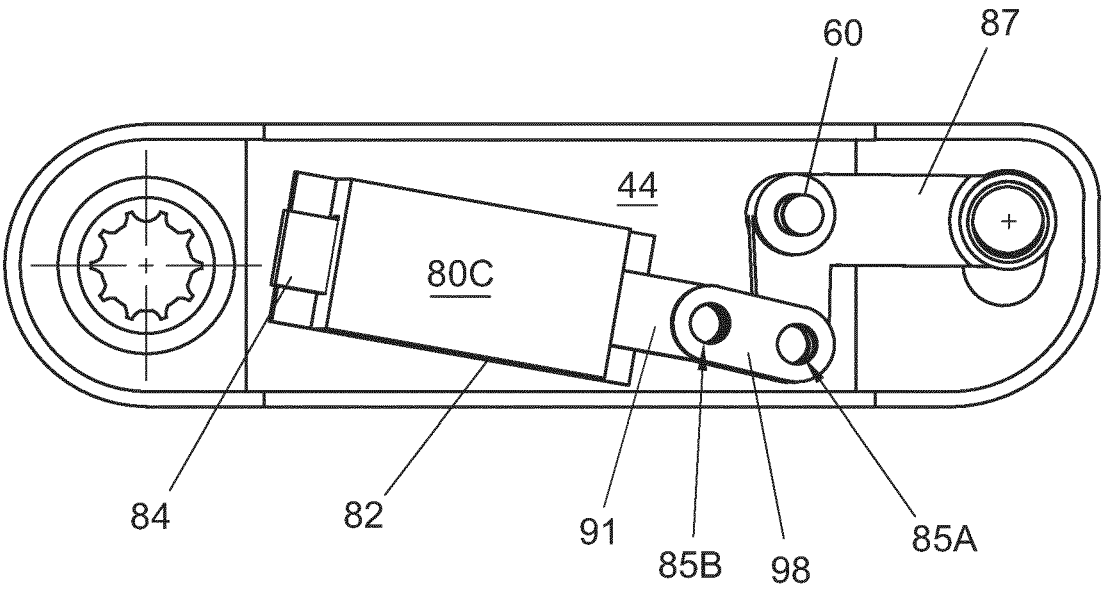

84
91
98
60
44
80C
41
82
85B
85A
87
41

FIG. 7G


60
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80C
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85B
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85A

FIG. 7H

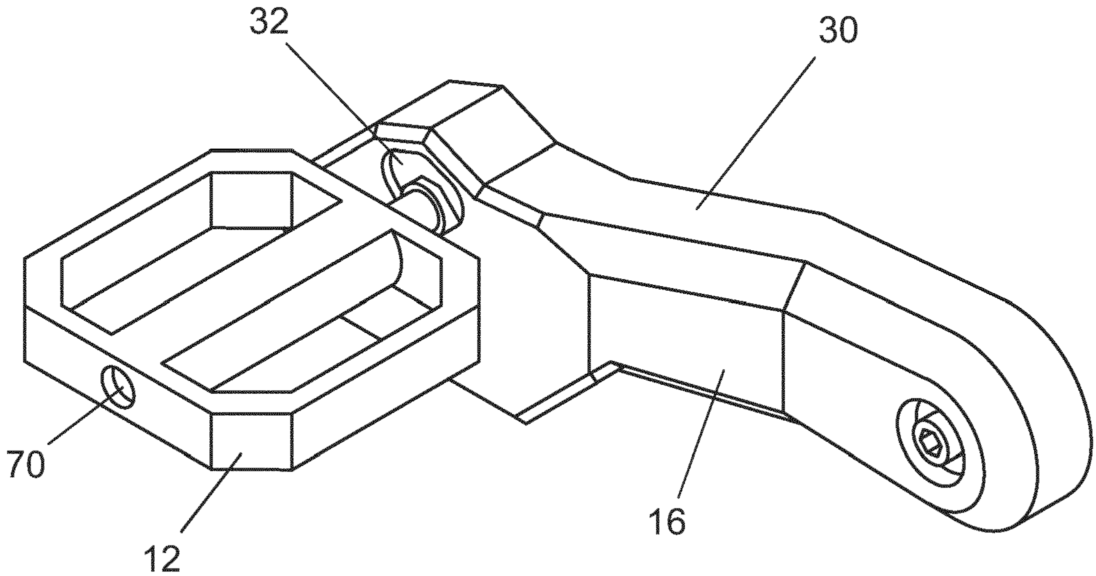


FIG. 8A

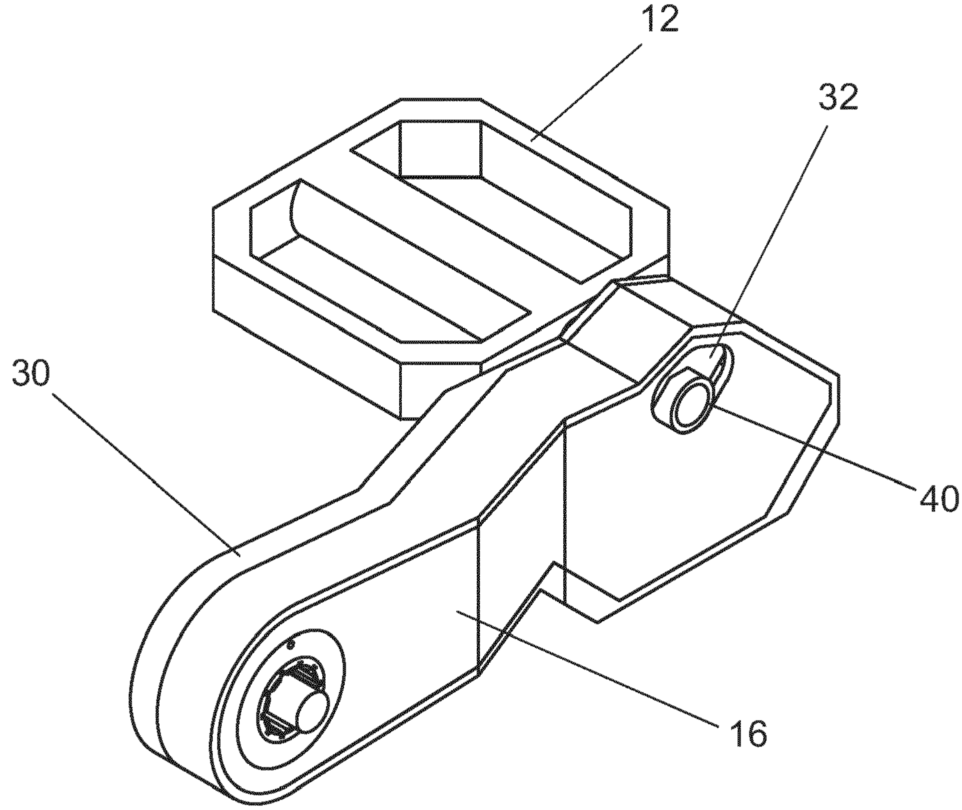


FIG. 8B

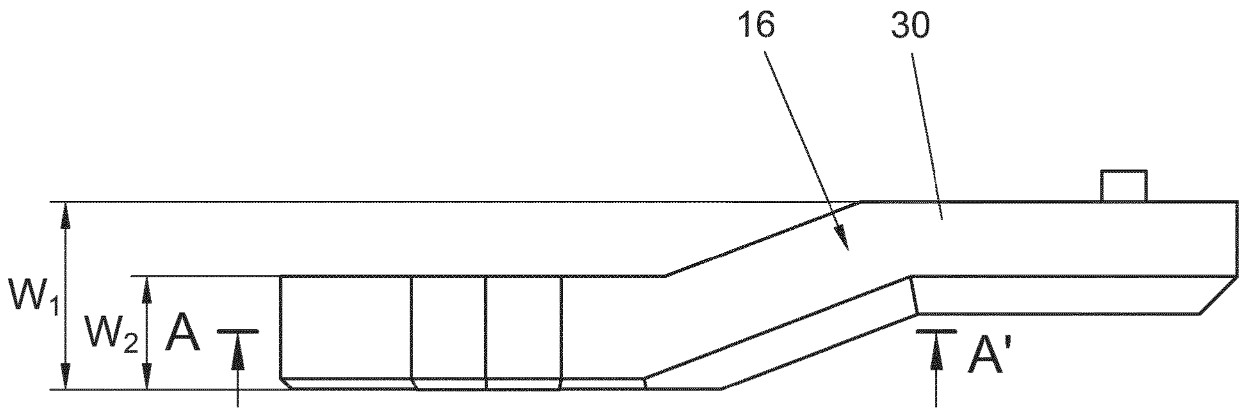


FIG. 8C

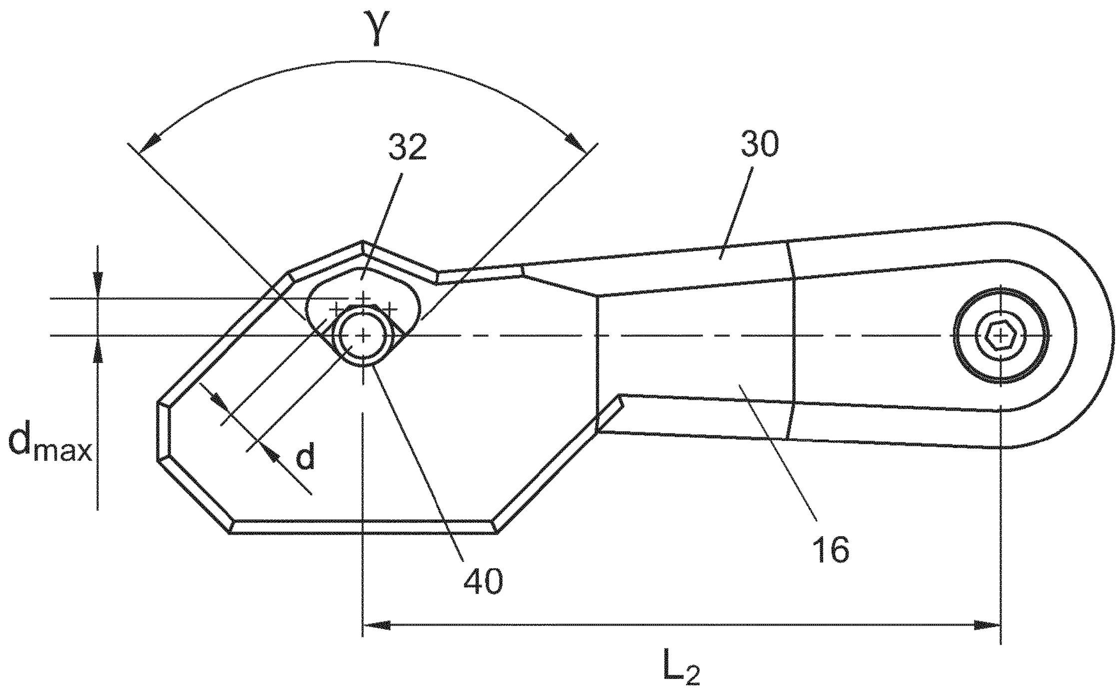
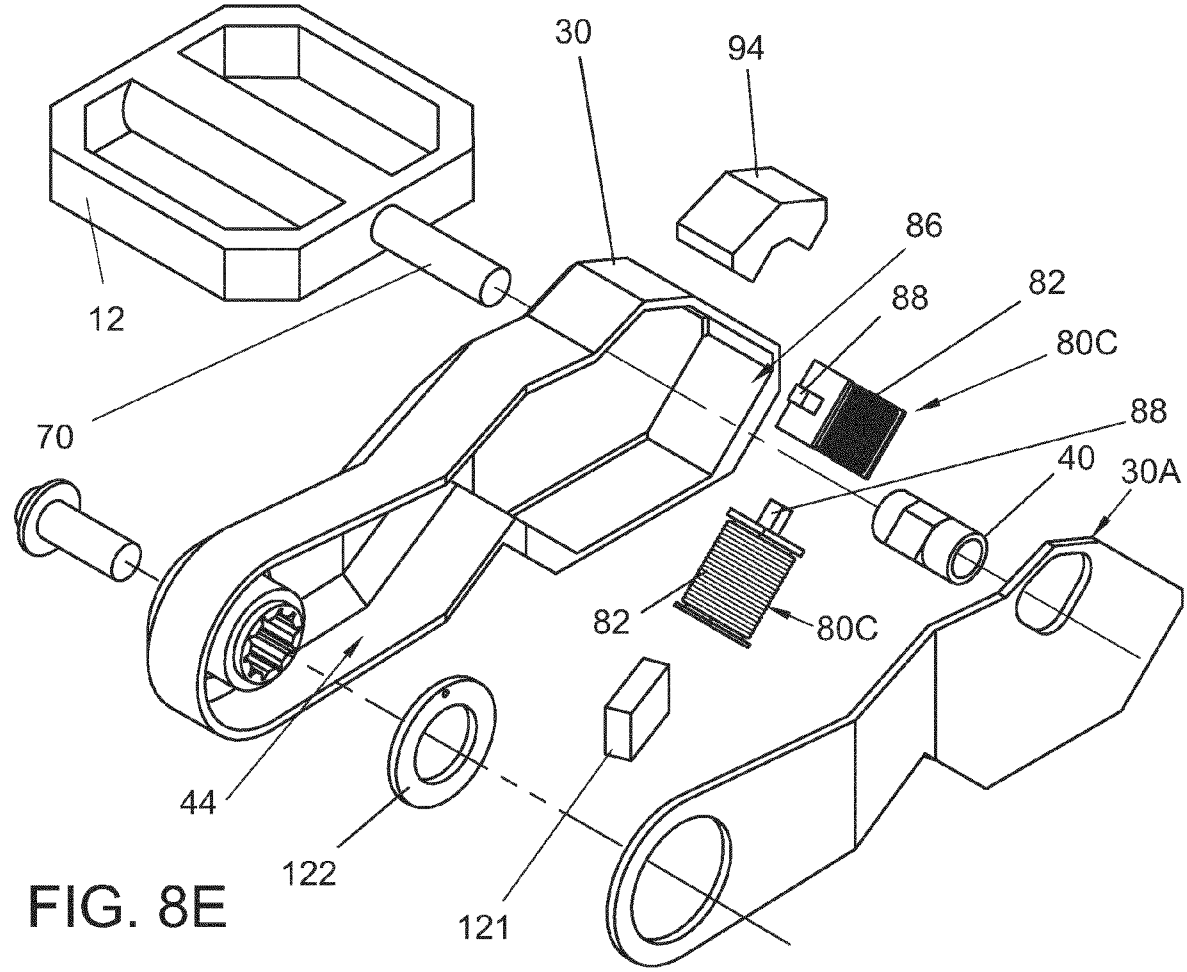


FIG. 8D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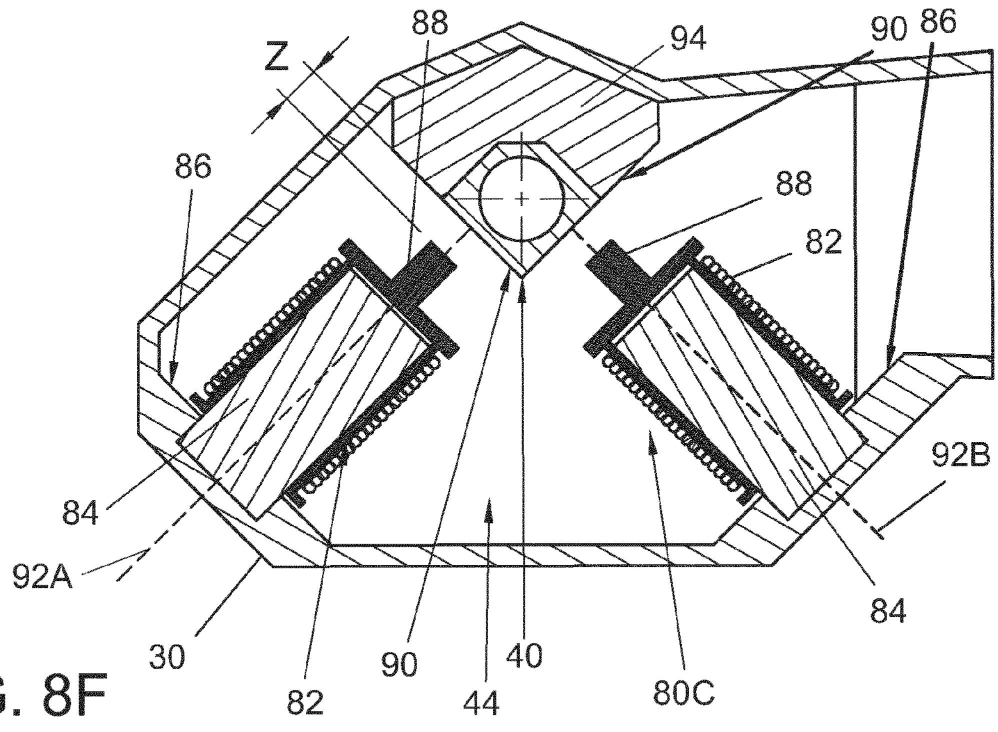
86
12
88
82
80C
70
88
40
30A
82
80C
44
122
121

FIG. 8E


Z
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92B
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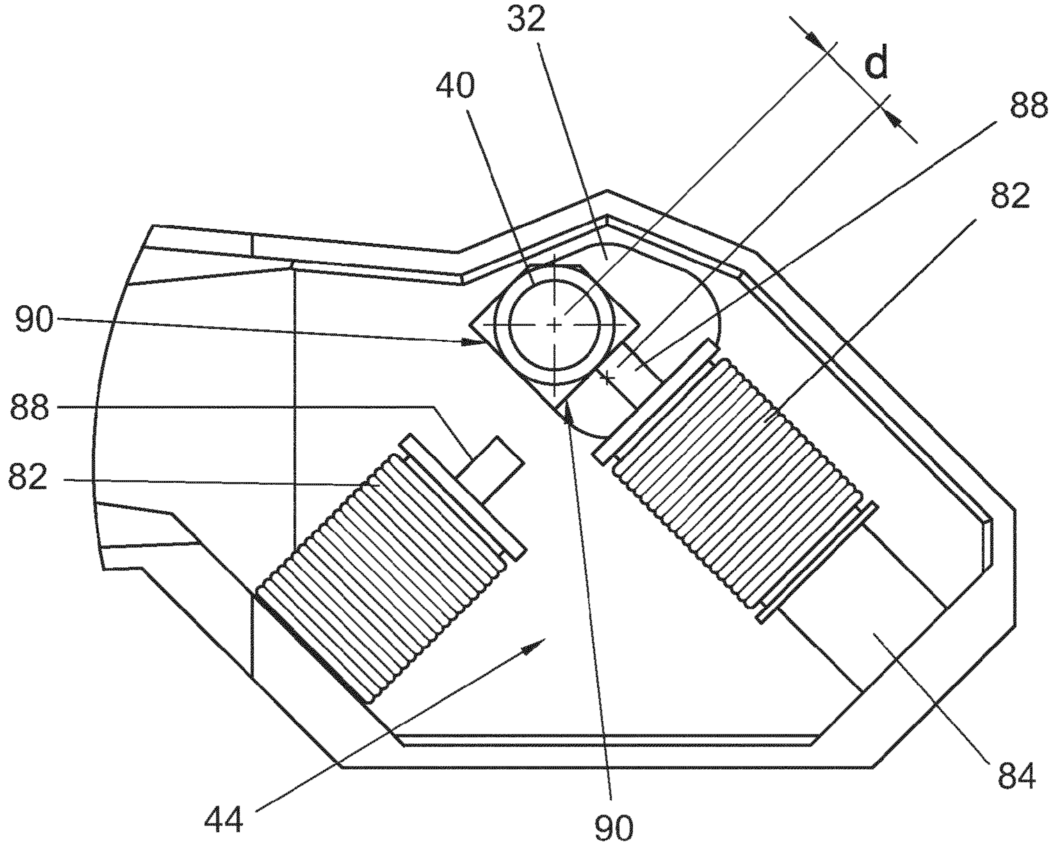
44
40
80C
84

FIG. 8F


32
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d
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82
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88
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44
90
84

FIG. 8G

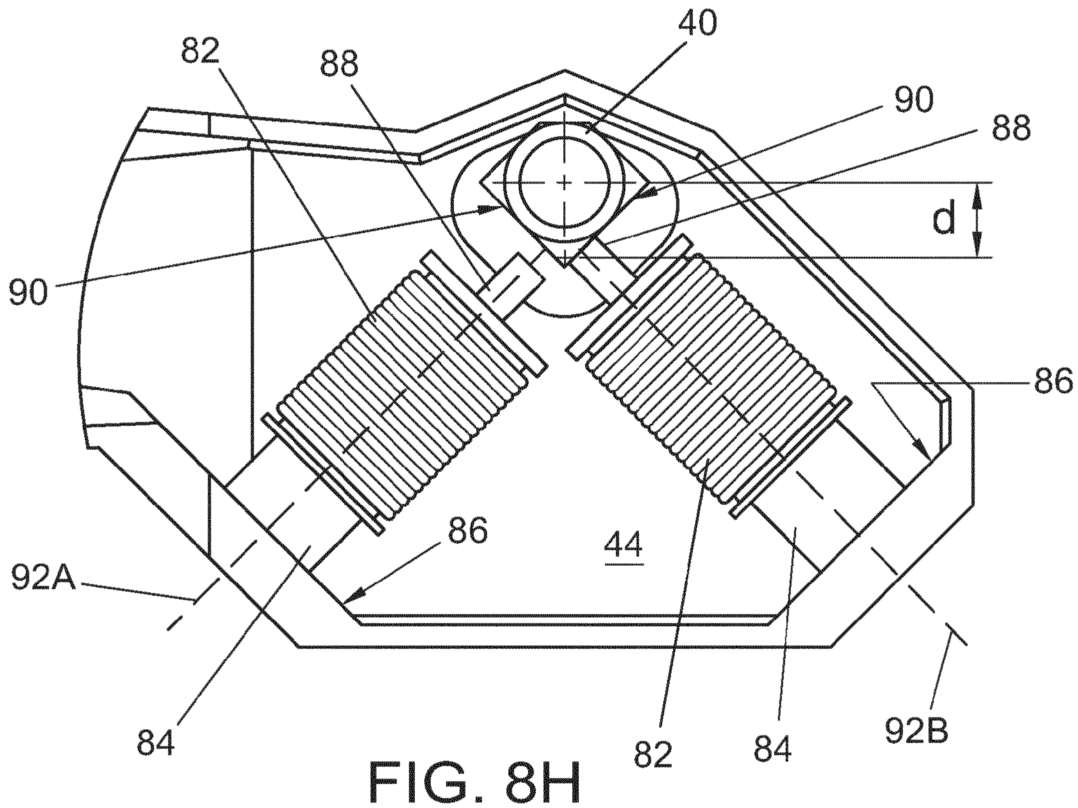

40
82
88
90
88
d
90
86
86
44
92A
84
82
84
92B

FIG. 8H

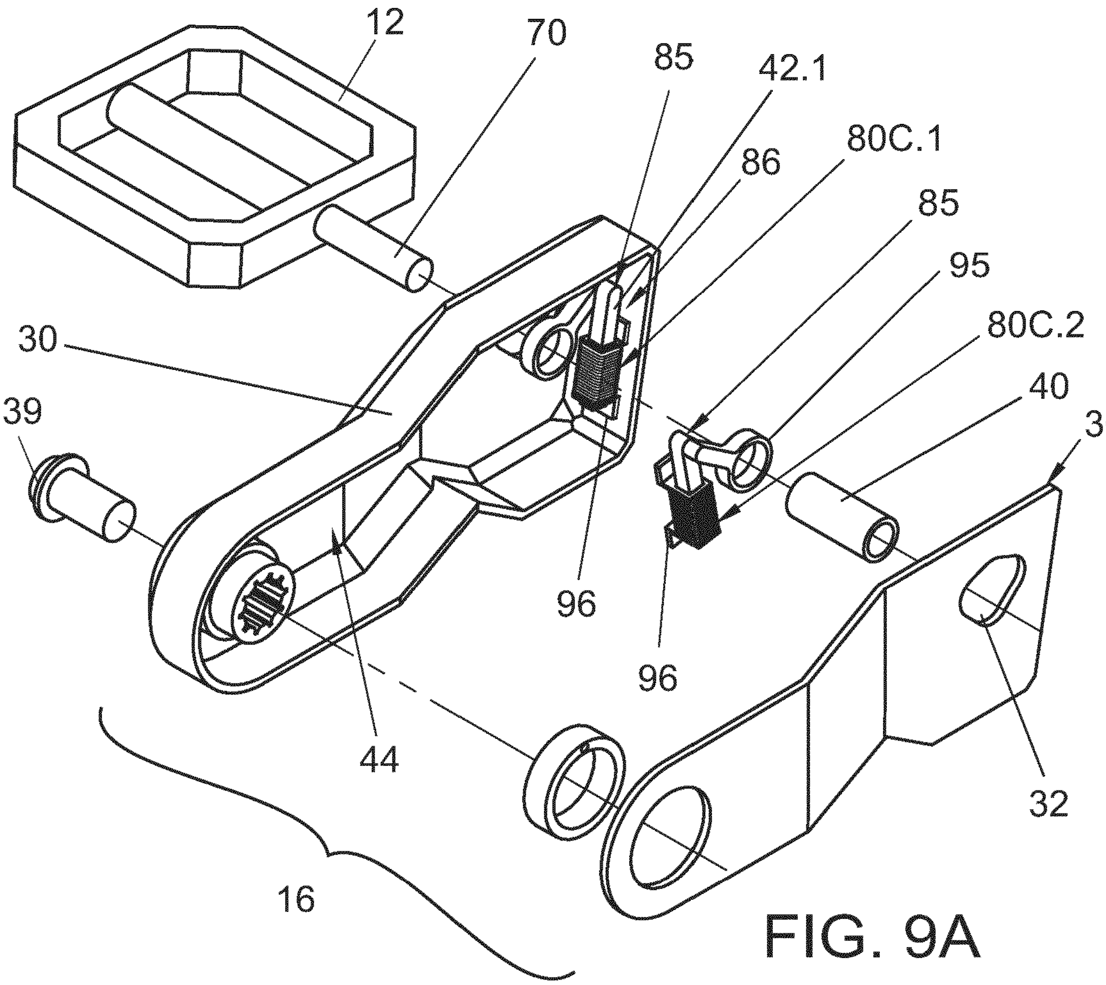

12
70
85
42.1
86
80C.1
85
95
80C.2
40
30A
30
39
96
96
44
32
16

FIG. 9A

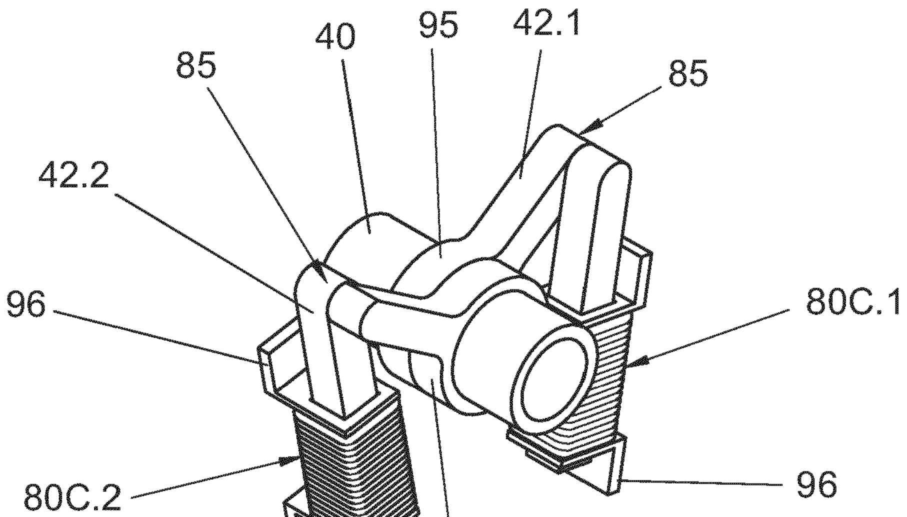

40
95
42.1
85
85
42.2
96
80C.1
80C.2
96
95

FIG. 9B

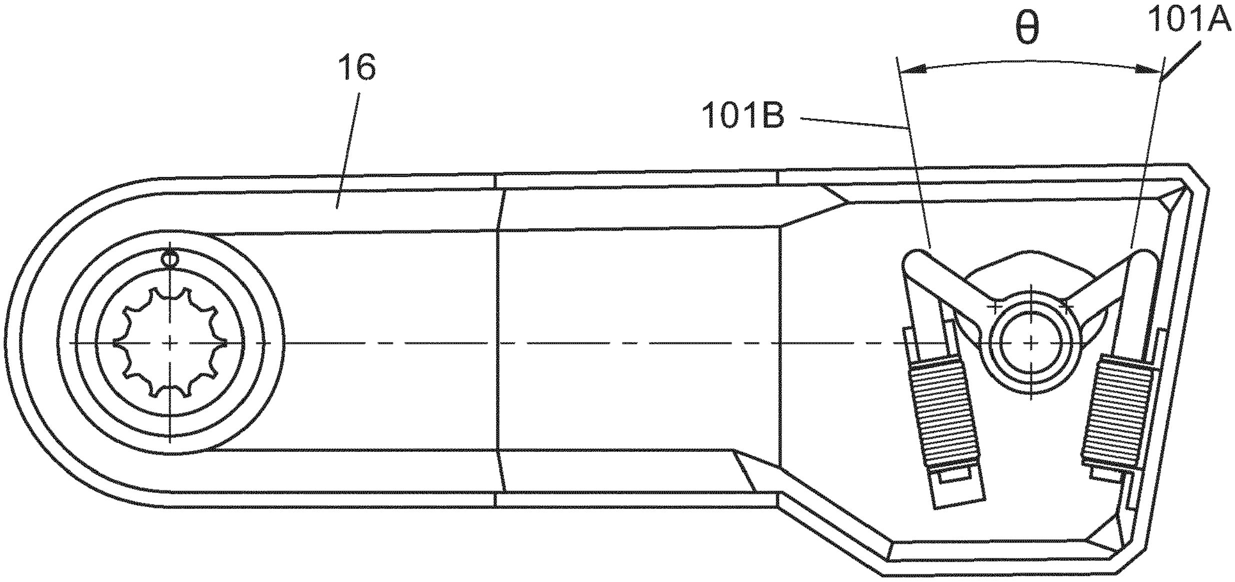


FIG. 9C

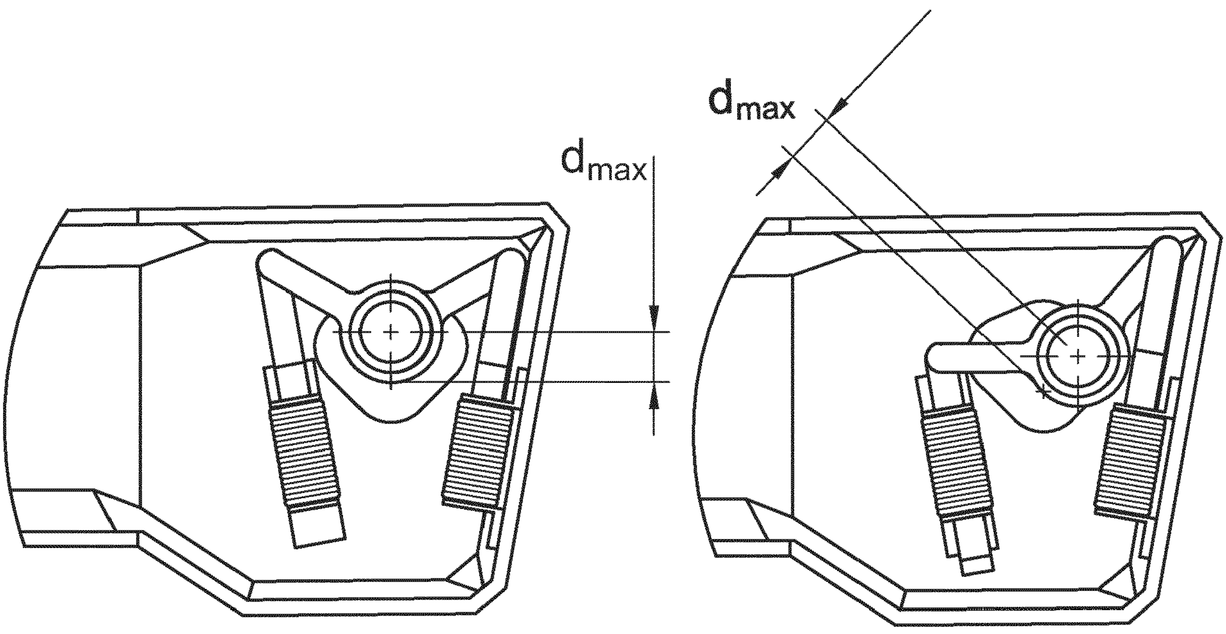
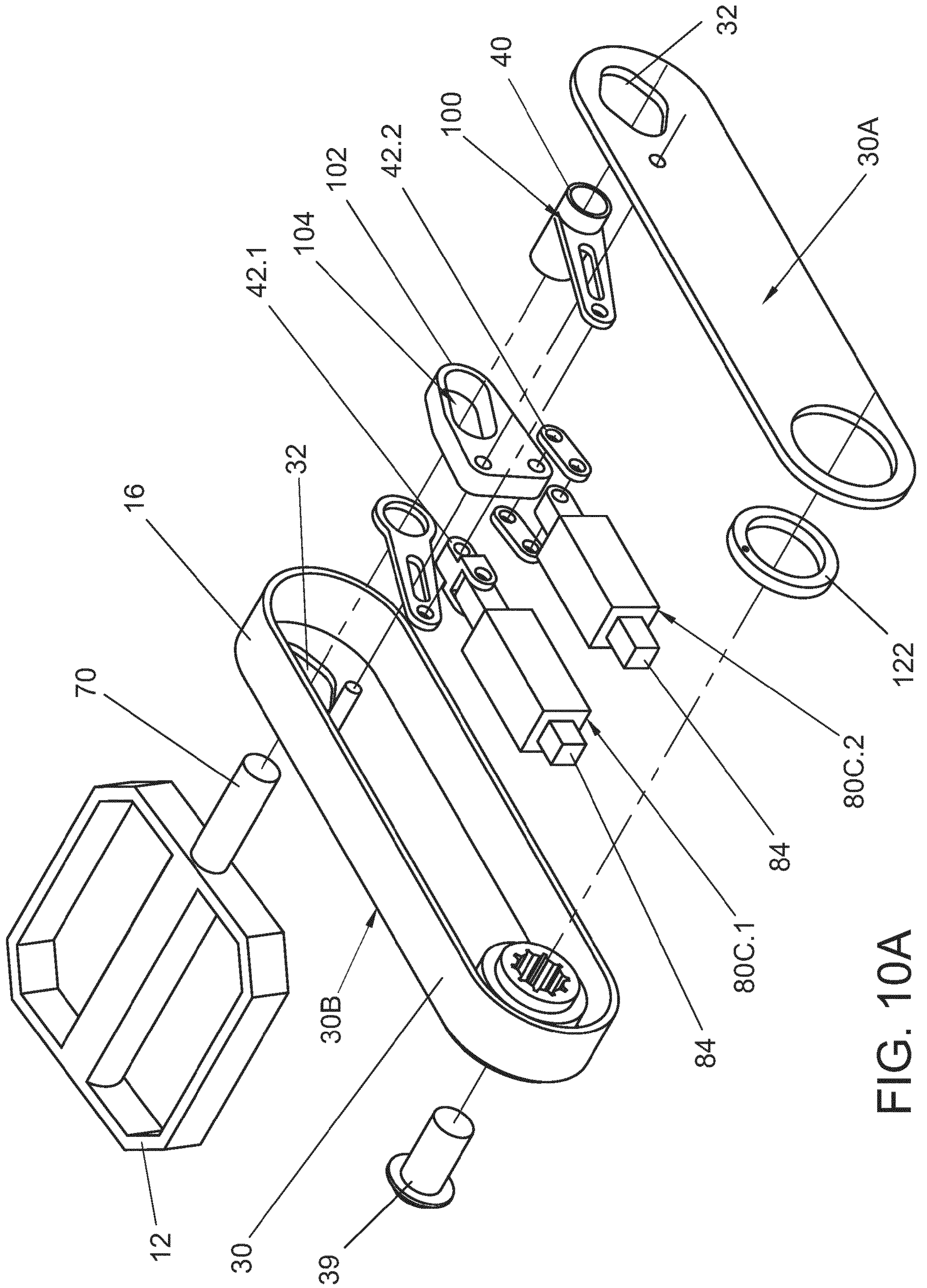


FIG. 9D

FIG. 9E



12
30
39
70
16
32
30B
84
80C.1
84
80C.2
122
42.1
104
102
42.2
100
40
32
30A

FIG. 10A

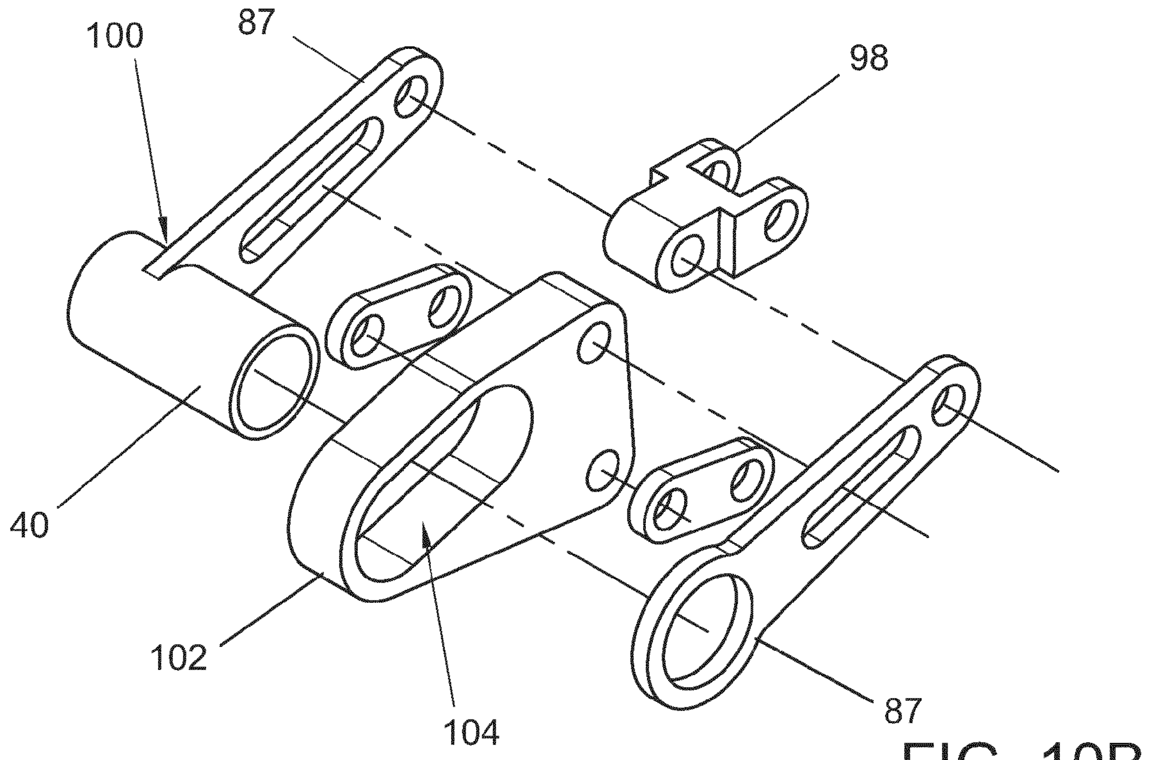


FIG. 10B

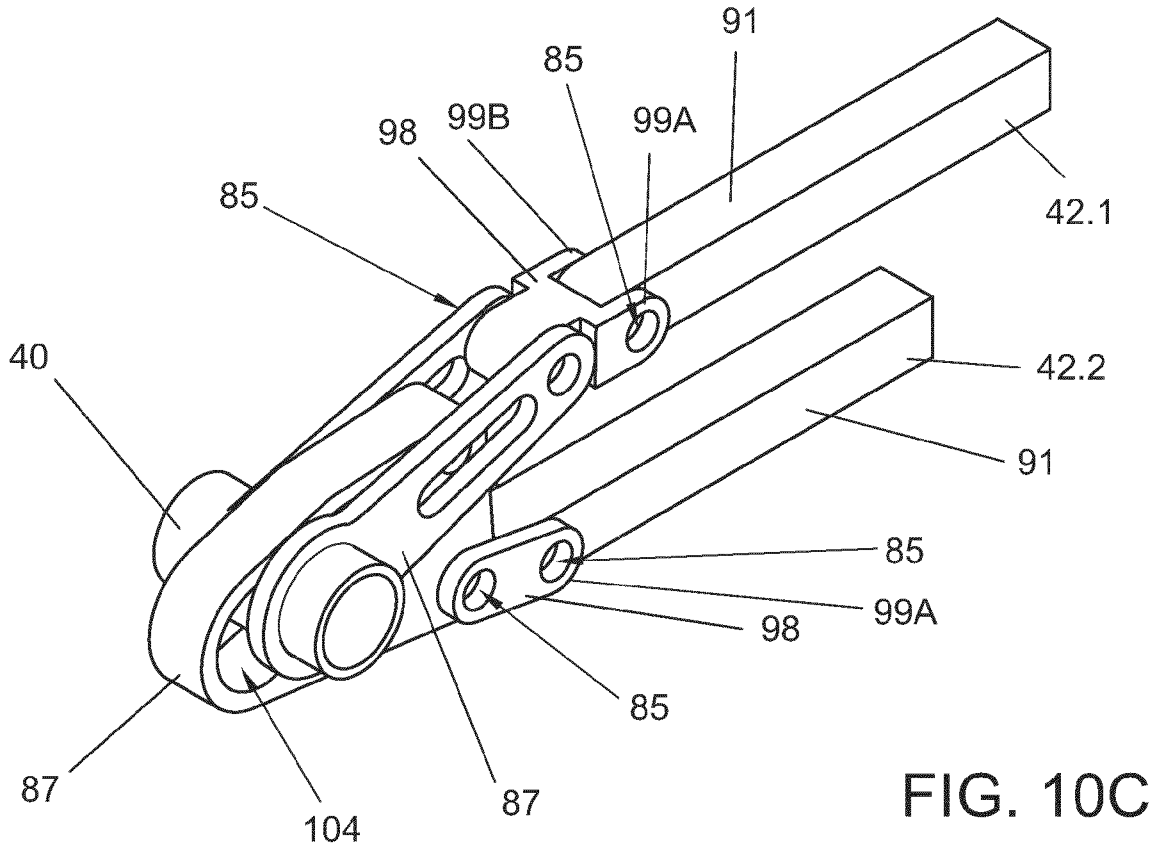


FIG. 10C

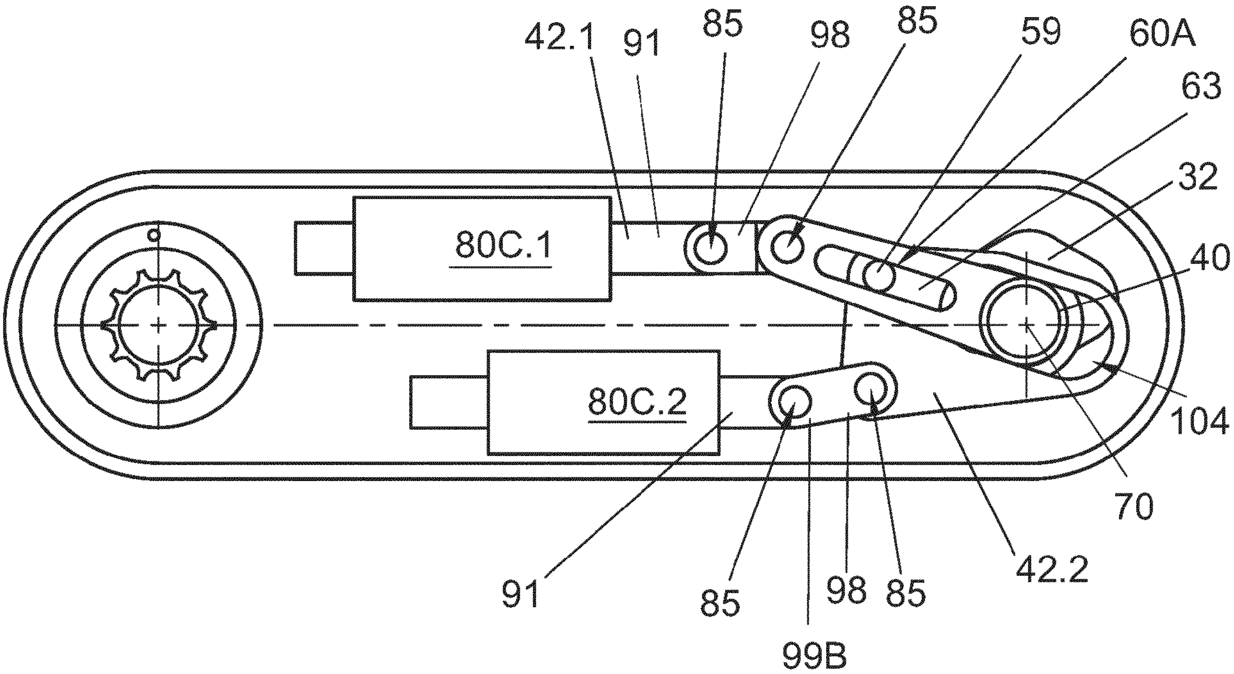


FIG. 10D

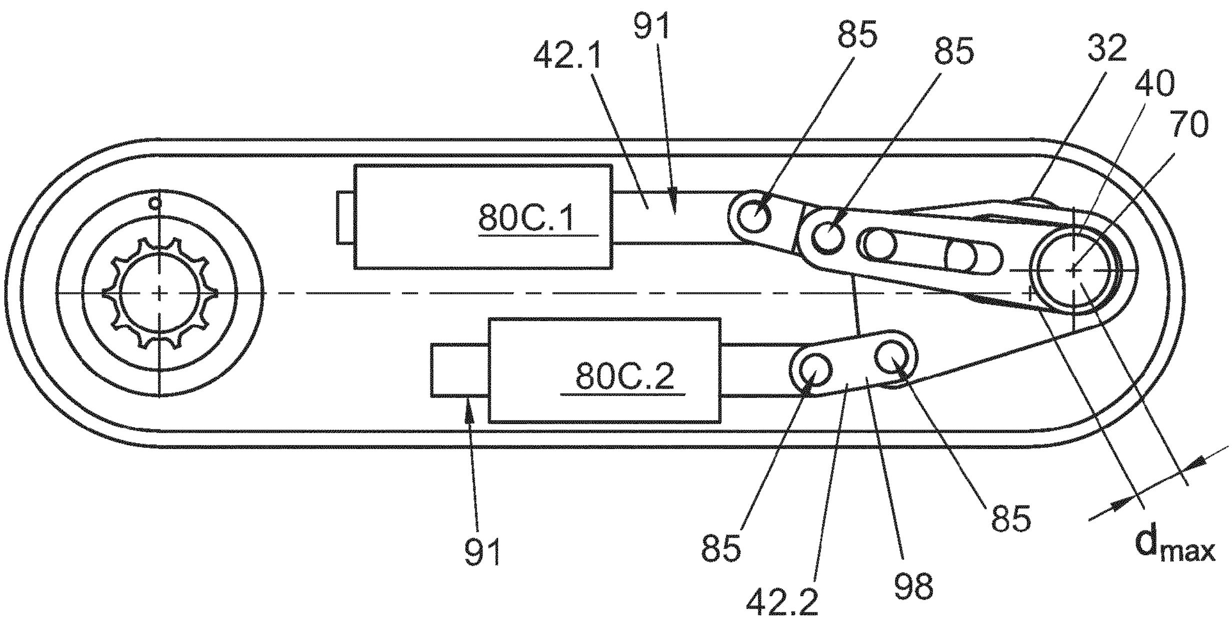


FIG. 10E

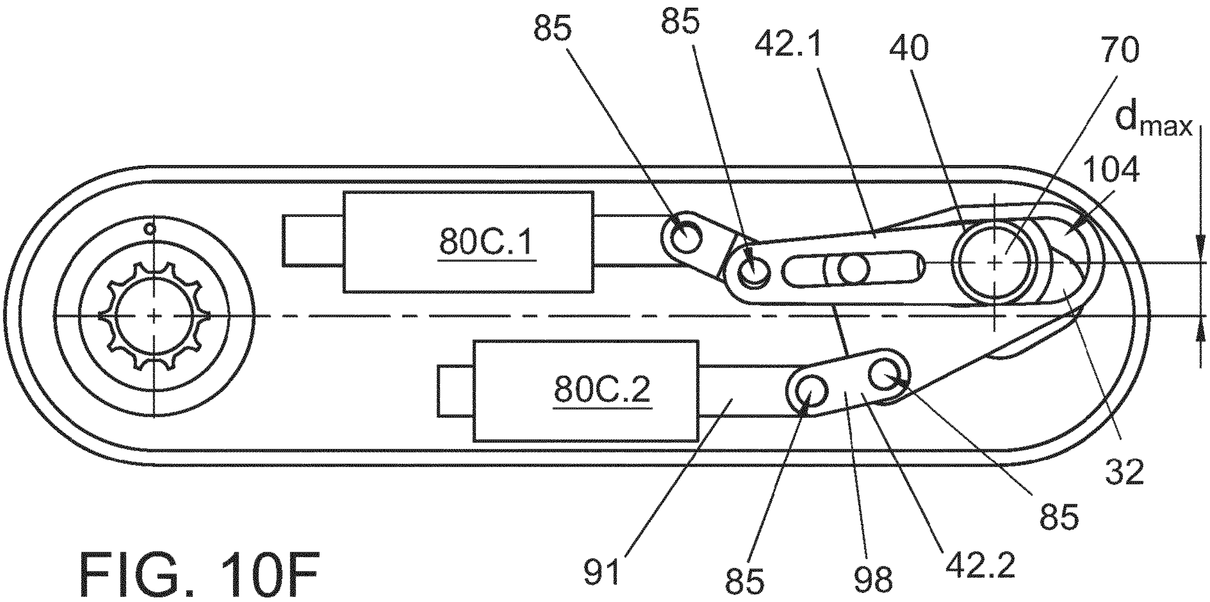


FIG. 10F

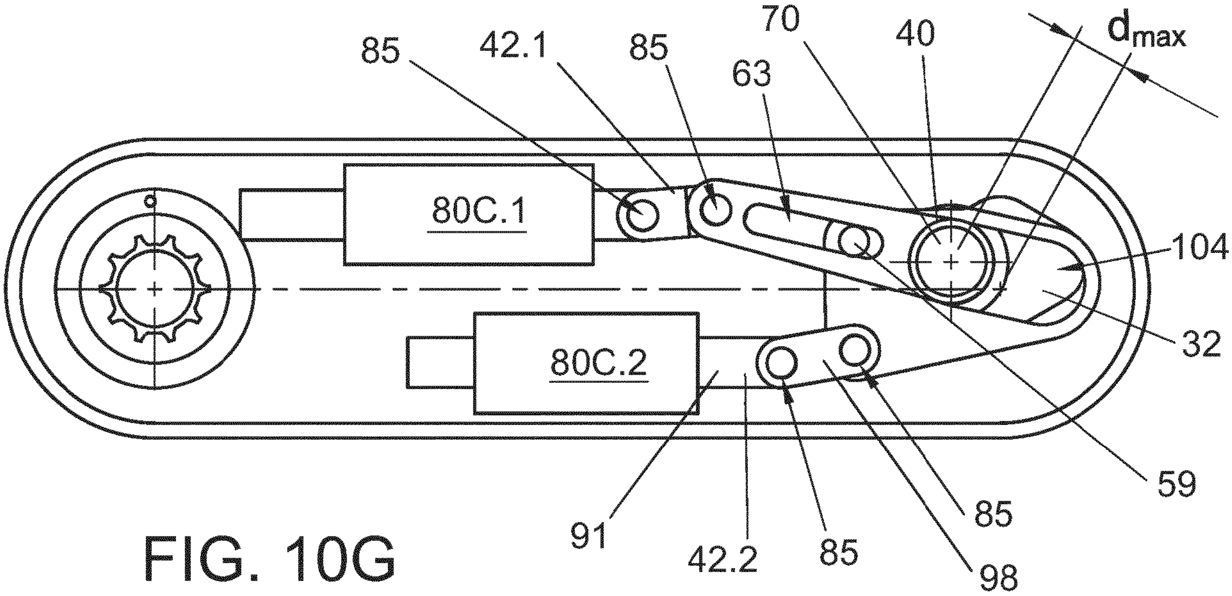


FIG. 10G

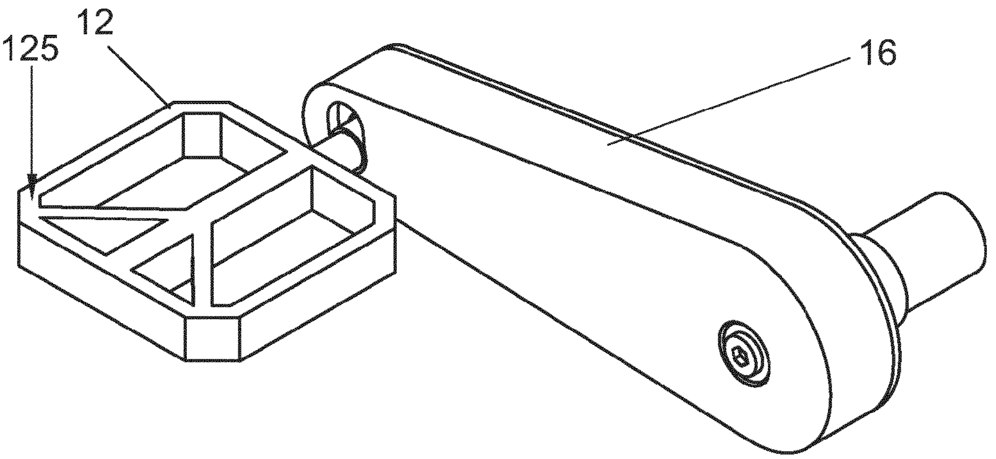


FIG. 11A

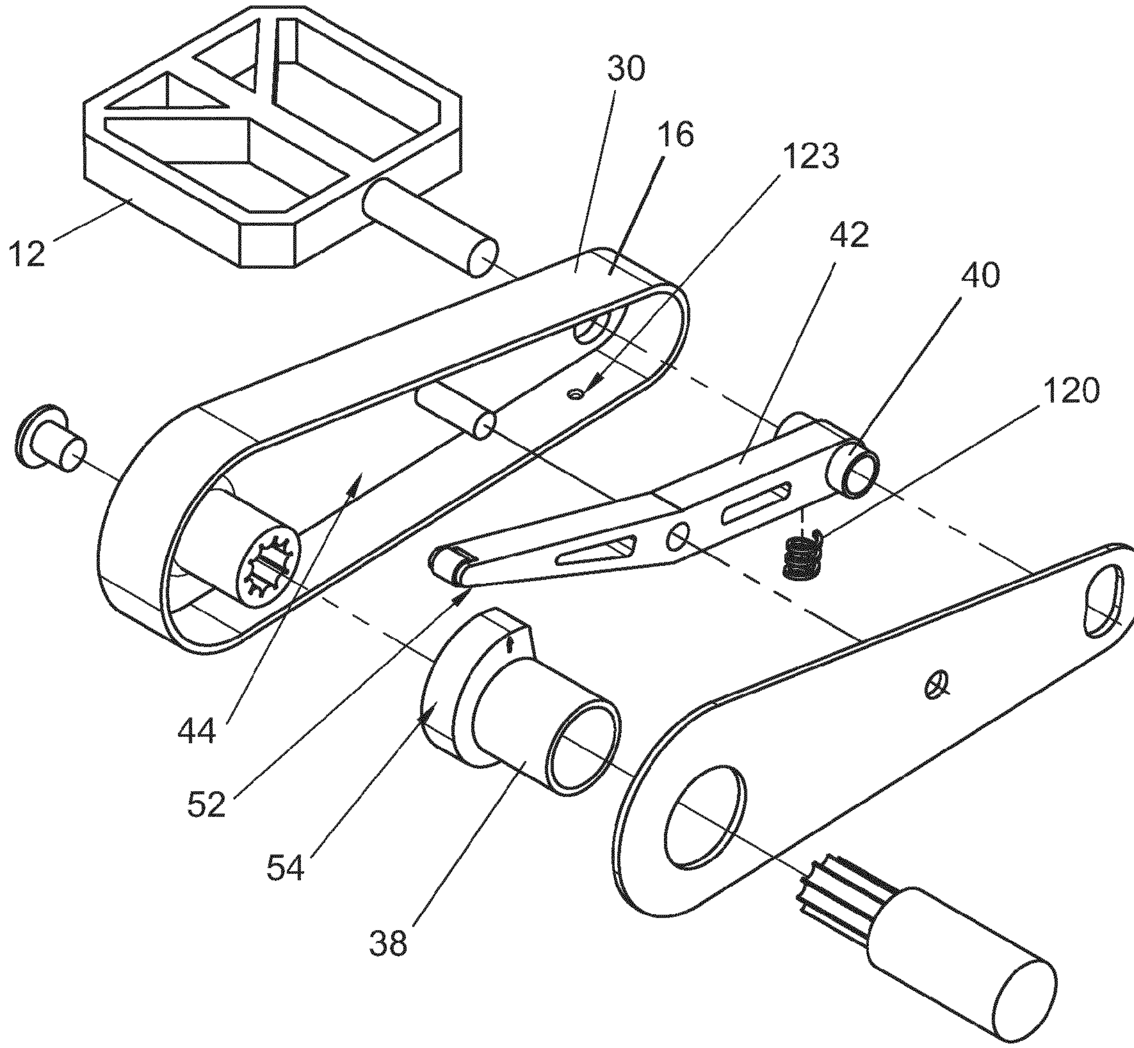


FIG. 11B

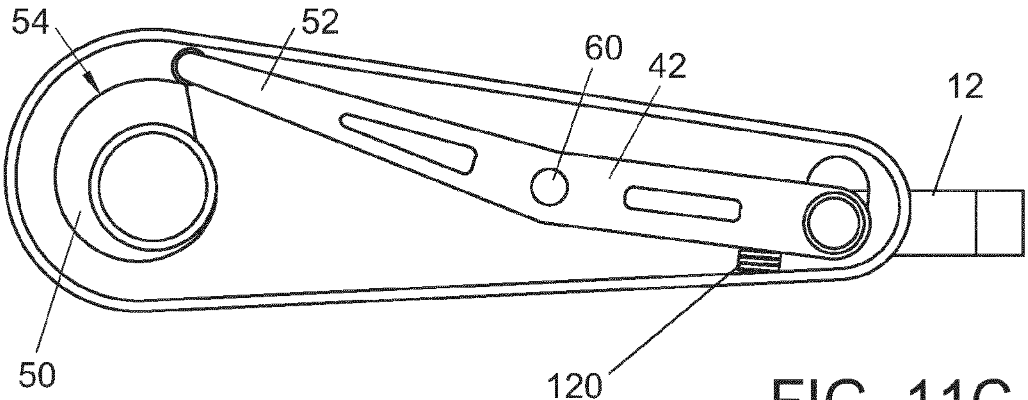


FIG. 11C

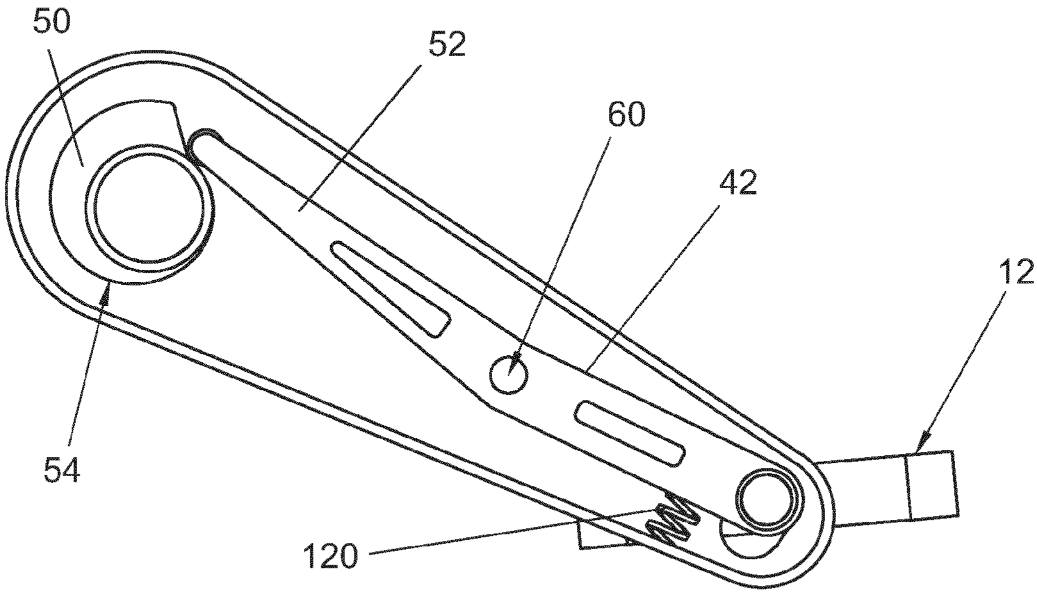


FIG. 11D

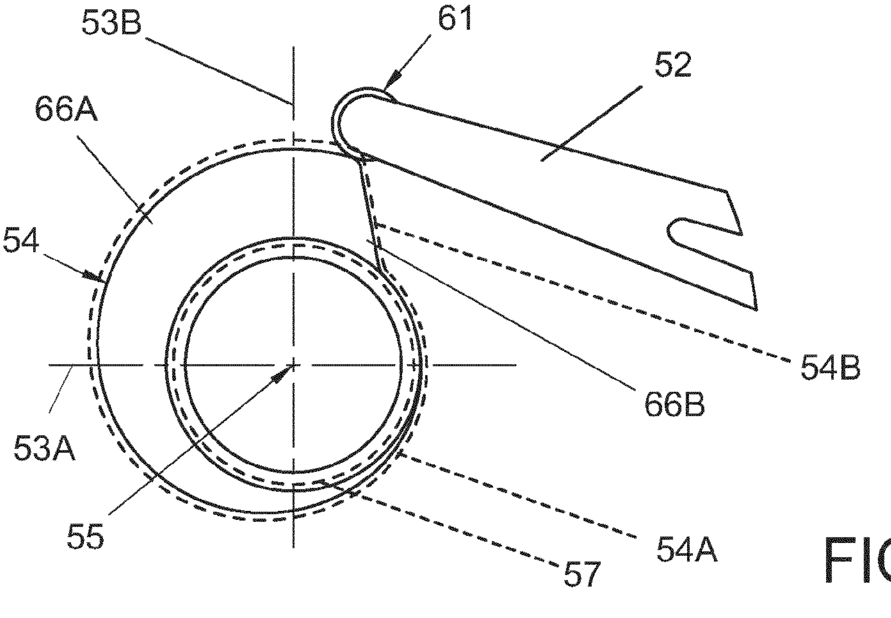


FIG. 11E

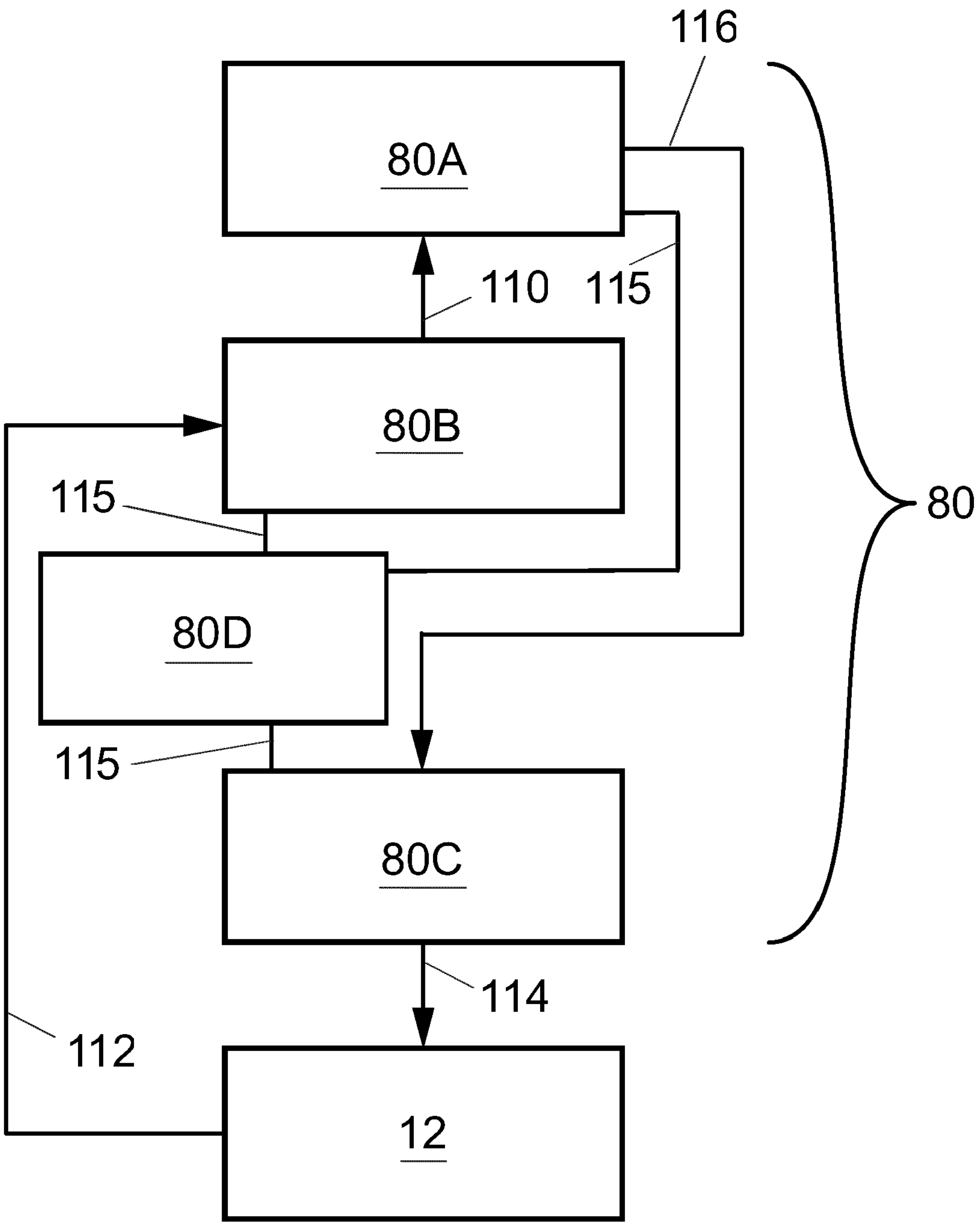


FIG.12

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EUROPEAN SEARCH REPORT

Application Number
EP 21 21 0625

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2020/155895 A1 (SCHINDLER-IVENS SHEILA [US] ET AL) 21 May 2020 (2020-05-21) * paragraph [0025] - paragraph [0058]; figures *	1-15	INV. A63B22/06 A63B23/035 A63B24/00 A63B22/00
X	US 2016/256731 A1 (TSENG GHUN-KAI [TW]) 8 September 2016 (2016-09-08) * paragraph [0034] - paragraph [0037]; figures *	1,11,12, 14,15	
X	US 7 727 125 B2 (DAY FRANKLIN J [US]) 1 June 2010 (2010-06-01) * column 7 - column 8; figures *	1,11,12, 14,15	
X	US 6 474 193 B1 (FARNEY MICHAEL KENT [US]) 5 November 2002 (2002-11-05) * column 4; figures *	1	
			TECHNICAL FIELDS SEARCHED (IPC)
			A63B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	14 April 2022	Borrás González, E

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14-04-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2020155895 A1	21-05-2020	NONE	
US 2016256731 A1	08-09-2016	JP 3198173 U	18-06-2015
		TW 201632228 A	16-09-2016
		US 2016256731 A1	08-09-2016
US 7727125 B2	01-06-2010	US 2006094569 A1	04-05-2006
		WO 2006050137 A2	11-05-2006
US 6474193 B1	05-11-2002	US 6474193 B1	05-11-2002
		US 6820517 B1	23-11-2004

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Patent documents cited in the description

- US 4570927 A **[0011] [0013] [0016]**
- US 20140024502 A **[0012] [0013] [0016]**

Non-patent literature cited in the description

- Physical Activity and Bone Health. **WENDY M. KOHRT et al.** Medicine & Science in Sports & Exercise. American College of Sports Medicine, 2004, 1985-1996 **[0071]**
- **YEOU-FANG HSIEH ; CHARLES H. TURNER.** Effects of Loading Frequency on Mechanically Induced Bone Formation. *Journal of Bone and Mineral Research,* 2001, vol. 16 (5 **[0103]**