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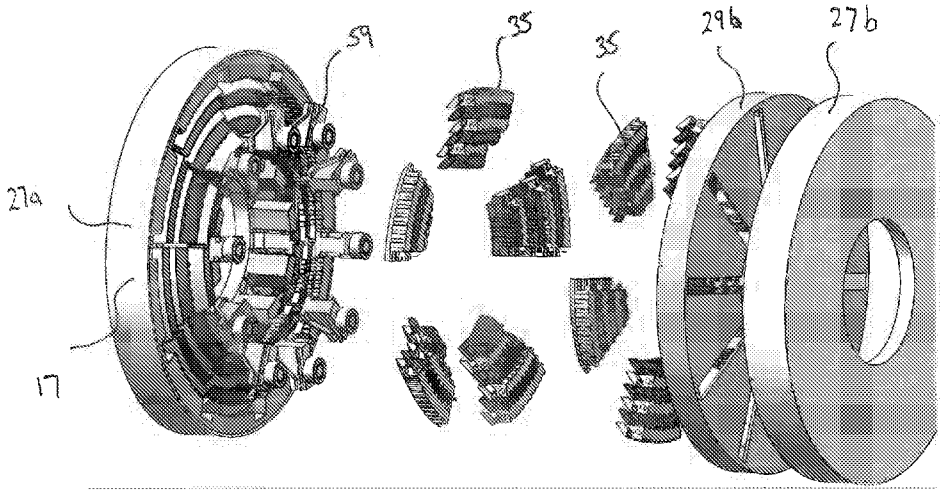

Figure 7

(57) Abstract: The present invention provides a transmission system (12) comprising a first pulley (11) connected to an output (111) by a cable (40) such that movement of the first pulley causes rotation of the output. The first pulley comprises an annular recess (25) between a first side (17) of the first pulley and a second side (19) of the first pulley. The annular recess is adapted to receive the cable such that the cable is supported by the first pulley. The first pulley also comprises a pair of support surfaces (31) located in the annular recess. The pair of support surfaces are moveable in a lateral direction relative to the sides of the pulley between a spaced condition, wherein the first pulley is at a first diameter and the pair of support surfaces do not engage the cable, and a meshed condition, wherein the first pulley is at a second diameter and the pair of support surfaces support the cable, the second diameter being larger than the first diameter.

WO 2019/010539 A1

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A Pulley and Transmission System

TECHNICIAL FIELD

[0001] The present invention generally relates to a pulley. In particular the present invention relates to a pulley which is capable of presenting a variable diameter. The present invention also relates to a transmission system, or pulley driven system, which incorporates the pulley.

BACKGROUND ART

[0002] The following discussion of the background art is intended to facilitate an understanding of the present invention only. The discussion is not an acknowledgement or admission that any of the material referred to is or was part of the common general knowledge as at the priority date of the application.

[0003] Transmission systems are used in various vehicles and industrial equipment to transfer power from a power source to an output, typically to a drive wheel to move the vehicle. One such vehicle which employs a drive train is a bicycle.

[0004] The transmission system of a bicycle is typically in the form of a centrally located chain ring integrating two crank arms. A rider engages the crank arms to rotate the chain ring. The chain ring is spaced from a rear sprocket but is interconnected using a chain which spans between the chain ring and the sprocket. As a result the torque exerted on the chain ring is transferred to the rear sprocket, which is also caused to rotate. The rear sprocket is secured to the axle of the rear wheel of the bicycle such that as the rear sprocket rotates the rear wheel will simultaneously rotate.

[0005] The transmission system of a bicycle will typically further comprise a gearing system to enable a rider to manipulate the effect the rotational force of the chain ring has on the rear wheel. This gear system general comprises a plurality of co-axially mounted rear sprockets of different diameter and a plurality of co-axially mounted chain rings (usually between one and three) of different diameter. By activating a gear mechanism the rider can cause the chain to move to different sprockets or chain rings, enabling the rider to choose the gear ratio which best suits the conditions.

[0006] Current gearing systems are limited in the gear range they can achieve. A bike can either be set up with a large gearing range thereby not featuring the smallest possible gears, or with a small ‘compact’ gearing range thereby not featuring the largest possible gears. Therefore when setting up a bicycle it is necessary to choose one of the subset ranges.

[0007] A large gearing range is used for relatively flat terrain but inevitably leads to undesirable limitations when sections of the predominantly flat terrain lead uphill at a notable gradient, as these cannot be ridden with the preferred small gearing. This in turn leads to rider fatigue and a competitive disadvantage. A small gearing range is used for relatively steep uphill terrain but leads to undesirable limitations when riding downhill as large gearing to facilitate pedalling downhill at high speeds is not available. This leads to lower than possible speeds and hence a competitive disadvantage.

[0008] On a practical level the gear ratio range limitations of existing state of the art chain driven derailleur systems mean that riders and mechanics have to make a call on whether to install a large or small gear range. This not only compromises riding efficiency but also means a constant mechanical effort in changing and replacing the systems on the bike between race days of any tour event. The same applies to recreational riders who have to go through the effort of replacing drive trains depending on their intended type of riding if they want to expend riding energy efficiently.

[0009] While chain driven derailleur systems are highly efficient in transferring rider energy from the crankset to the rear wheel, this efficiency is significantly diminished when the chain is not set in a straight line between the plane of the front chain sprocket and the plane of the rear sprocket plane, i.e. all three elements are not in the same plane. Due to the inherent limitation of this type of drivetrain, straight line chain setting is only achievable for a small subset of gear settings of the drive train gearing range.

[0010] When a gear setting is chosen that causes the chain to deviate from the straight line between the chosen front chain ring and the chosen rear sprocket, the resultant strains and friction within the chain, and between chain and the chain ring and sprocket cause drive train efficiency to drop markedly. This means that up to 20% of the rider's energy provided at the crank set does not arrive at the rear wheel. The rider has no choice but to select terrain induced gear settings that feature this inefficiency because it would be even less desirable to force the rider's body to cope with too high or too low gear settings just for the sake of drive train efficiency.

[0011] An issue for chain driven derailleur or any discrete gearing systems is that the process of changing gears results in a temporary loss of power transmission for the time it takes the chain to relocate from one chain ring or sprocket to another one. This results in notable loss of rider energy in particular when riding uphill at steep gradient, as the resulting loss of momentum during gear change requires additional effort to bring the bicycle back to the speed before the gear change. It also leads to a time delay in the opportunity to respond to another rider's sprint during a race situation, all of which constitutes a competitive disadvantage and may make the difference between winning or not winning a road race.

[0012] Chain driven derailleur systems also feature inherent discontinuous gearing when changing chain rings which result in the need to simultaneously change sprockets. This compounds the loss of momentum problem. It also presents a significant challenge to fatigued riders and frequently leads to inefficient riding.

[0013] Another disadvantage of conventional chain driven derailleur systems is the inability to change gear when stationary. Chain driven systems require a pedalling cadence to be applied in order to facilitate gear change. When a rider unexpectedly has to come to a stop or slow down there is a loss in rider energy and ultimately chain drive train efficiency, as the rider must first change to a smaller gear starting from a much too large gear. This consumes a disproportionate amount of energy and the cumulative effect of that over long rides leads to reduced rider endurance.

[0014] Chain and derailleur driven bicycle drive trains have been refined over several decades but still feature unavoidable weight in their components, particularly the chain itself which can only practically be manufactured from heavy steel.

[0015] Chain driven derailleur systems are sensitive to physical shocks to the bike, lack of mechanical calibration quality or other misalignment, componentry mismatch, and lack of sensible rider operation. If any of the above exceeds the limitation of their operational design, the chain will come off the chain ring or the sprocket and, in the worst case, the chain can break. Chain derailment is common in recreational cycling and even regularly occurs during professional road racing even though great care is taken to provide equipment in peak condition. Other mechanical failures for conventional chain drives include blockage of some of the gear ratios by dirt ingress or ice formation.

[0016] Conventional chain driven systems and also other hub gearing systems require lubrication in order to operate at peak efficiency possible. The systems are very sensitive to suboptimal lubrication which leads to regular maintenance requirements that are an operational overhead as well as a cost. Furthermore, new chains only become efficient after a ‘break in’ period that removes friction inefficiencies resulting from manufacturing processes. They then need to be regularly cleaned at short intervals or significant inefficiencies are introduced.

[0017] Chain driven derailleur and also hub planetary gearing systems are subject to high wear rates between the two metallic surfaces interacting, i.e. either the steel chain and the teeth on a sprocket or chain ring, or the planetary gear sprockets in a hub. This reduces part life cycles and means the entire drive train needs regular replacement in order to provide efficient power transfer.

[0018] The above discussion of the background art is intended to facilitate an understanding of the present invention only. While the discussion focusses on transmission systems of bicycles, it would be readily understood that similar problems exist in transmission systems used in other applications.

SUMMARY OF INVENTION

[0019] It is an object of this invention to provide a pulley and a transmission system comprising the pulley which ameliorates, mitigates or overcomes, at least one disadvantage of the prior art, or which will at least provide the public with a practical choice.

[0020] While the invention has been shown and described with particular reference to a bicycle, the invention is equally applicable in many other applications. For example the invention has application in most cable/chain/belt/pulley driven systems which currently use different gear ratios to achieve a particular outcome. These other applications include, but are not limited to transmission systems in vehicles, motorcycles, lawn mowers, quadbikes, pumps, generators, manufacturing equipment including cnc machines, and other industrial mobile equipment, as well as fixed cable/belt driven machinery. These other applications, as well as those which would be obvious to the person skilled in the art, are considered to be included in the scope of the invention as defined herein.

[0021] Throughout the specification the term 'cable' is used to describe a rope, a belt, a chain, webbing or any other rope-like device which may be used to assist in transmitting force from a pulley to another object. Furthermore the term 'cable' can denote a single unitary cable, or a cable made from many smaller cables entwined, joined in an end to end arrangement or otherwise formed to provide a substantially unitary member.

[0022] The present invention provides a transmission system, the transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes movement of the output, the first pulley comprising:

a first side assembly spaced from a second side assembly, the first side assembly and second side assembly are rotatably fixed together;

a variable annular recess defined between the first side assembly and the second side assembly, the annular recess being adapted to receive the cable;

each of the first side assembly and the second side assembly providing a support surface for supporting the cable, the support surface is laterally movable between a first position and a second position, the first position being spaced outwardly from the second position, the support surface of the first side assembly and the support surface of the second side assembly co-operate to engage the cable when the support surface of each side assembly is

in the second position, whereupon the cable moves from a first diameter to be supported at a second diameter;

the support surface comprises a plurality of support surface units, define the support surface, each support surface unit may move relative to each other;

wherein the width of the first pulley remains constant as the support surface moves between the first diameter and the second diameter, and vice versa.

[0023] Preferably the transmission further comprises at least one actuator apparatus for moving each support surface between the first position and the second position, the at least one actuator apparatus moves radially relative to the first side assembly and the second side assembly.

[0024] The at least one actuator apparatus may move radially relative to an axis of rotation of the first pulley. The at least one actuator apparatus may be variably positioned along a radial extent of the first pulley.

[0025] Preferably the at least one actuator apparatus comprising a first actuator and a second actuator connected therebetween by a bridge member.

[0026] Preferably the first actuator co-operates with the support surface of the first side assembly and the second actuator simultaneously co-operates with the support surface of the second side assembly to move each support surface between the first position and the second position.

[0027] The bridge member maintains the first actuator and the second actuator in a fixed relation. This ensures each support surface, when engaged by the at least one actuator apparatus, is held in position by the at least one actuator apparatus and not caused to move laterally outward due to the force exerted thereon by the cable.

[0028] At least one or both of the first actuator and the second actuator provides a first guide means to cause the support surface to move to the second position. The first guide means may comprise a first guide surface which engages the support surface.

[0029] At least one or both of the first actuator and the second actuator provide a second guide means to guide the support surface to the first position. The second guide means may comprise a second guide surface which causes the support surface to move to the first position. The second guide surface may comprise an actuator channel which cooperates with a portion of the support surface to cause the support surface to move to the first position.

[0030] The pulley may comprise a control means to control the movement of the at least one actuator apparatus. The control means may constrain the at least one actuator apparatus such that the at least one actuator apparatus is limited to radial movement relative to each side assembly.

[0031] The control means may comprise at least one support channel which engages the at least one actuator apparatus to limit movement along the at least one support channel. The at least one support channel may extend in a radial direction relative to each side assembly such that the at least one actuator apparatus is limited to radial movement relative to each side assembly. The at least one actuator apparatus may be variably positioned along the radial extent.

[0032] The control means may comprise a support housing which supports the at least one actuator apparatus. The support housing may comprise a backing plate and a movement mechanism. The backing plate may be located at a position between the support surface and the movement mechanism.

[0033] The backing plate may incorporate the at least one support channel for restricting the movement of the at least one actuator apparatus to a radial direction.

[0034] The movement mechanism may cause the at least one actuator apparatus to move along the radial extent.

[0035] In one aspect of the invention the movement mechanism comprises a motor and a series of gears which co-operate with the at least one actuator apparatus to move the at least one actuator apparatus along the radial extent.

[0036] In another aspect of the invention the movement mechanism comprises a guide plate which is rotatable relative to the backing plate, where rotation of the guide plate causes the at least one actuator apparatus to move along the at least one support channel of the guide plate. In this aspect the movement mechanism also comprises a motor and a series of gears which rotatably co-operate with the guide plate to move the at least one actuator apparatus along the radial extent. The motor may be housed in a spindle and/or a bottom bracket of the bicycle frame.

[0037] The control means may also comprise one or more levers to cause the at least one actuator apparatus to move along the radial extent wherein the action of the levers determines the direction of the motor and the period in which it is activated. The one or more levers may be in wireless/Bluetooth communication with the motor,

[0038] In one embodiment of this aspect the guide plate is in the form of a scroll plate. The scroll plate may comprise a spiral formation. The spiral formation may be in the form of a spiral groove. The groove may be continuous. The groove may be continuous from a first end adjacent an outer periphery of the guide plate to a second end adjacent an inner periphery of the guide plate. The spiral formation may engage an end of the at least one actuator apparatus whereby rotation of the scroll plate will cause the end of the at least one actuator apparatus to move along the spiral, causing the at least one actuator apparatus to move along the at least one support channel in the backing plate. The at least one support channel may be

substantially perpendicular to the portion of the spiral passing across the at least one support channel.

[0039] In another embodiment of this aspect the guide plate incorporates at least one groove positioned to be in association with the at least one support channel of the backing plate. The at least one groove may engage with an end of the at least one actuator apparatus. The at least one groove may be angularly orientated relative to the at least one support channel such that rotation of the guide plate causes the at least one groove to move relative to the at least one support channel, the at least one actuator apparatus being forced to move by the at least one groove so as to move radially along the at least one support channel.

[0040] The end of the at least one actuator apparatus may provide a roller, the roller being adapted to engage with the groove, the roller assisting movement of the at least one actuator apparatus as the guide plate rotates.

[0041] In one aspect of the invention the support surface comprises a plurality of support segments arranged in a circular configuration wherein the overall appearance of each support segment is that of a truncated pie segment.

[0042] Each support segment comprises a subset of the plurality of support surface units. Considering a single support segment, each support surface unit is stacked one on top of the other wherein, in one embodiment, the support surface unit positioned closest to the rotational axis of the pulley is the smallest inner support surface unit, with each support surface unit thereafter increasing in length.

[0043] Preferably each support surface unit is restricted to axial movement relative to adjacent support surface units. Each support surface unit may have a spline arrangement therebetween, wherein the spline arrangement prevents tangential movement between adjacent support surface units.

[0044] Each support surface unit may comprise a limiting mechanism to limit axial movement between adjacent support surface units. The limiting mechanism may comprise a projection incorporated in each support surface unit wherein the projection is adapted to co-operate with a recess in an adjacent support surface unit. The limiting mechanism at least maintains the support surface units in the second position until the at least one actuator apparatus causes the support surface unit to move back to the first position.

[0045] In another aspect of the invention each support surface comprises a plurality of support surface units. Each unit is independently movable between the first position and the second position. Each unit is restricted to movement between the first position and the second position.

[0046] Each support unit is adapted to co-operatively engage the at least one actuator apparatus wherein the at least one actuator apparatus causes each support unit to move between the first position and the second position.

[0047] Preferably the at least one actuator apparatus engages the support surface units to cause the support surface unit to move between the first position and the second position as the at least one actuator apparatus moves radially outward along the at least one support channel. Preferably the first guide surface of the at least one actuator apparatus engages the one or more support surface units.

[0048] Preferably the at least one actuator apparatus engages one or more support surface units to cause the support surface unit to move between the second position and the first position as the at least one actuator apparatus moves radially inward along the at least one support channel. Preferably the second guide surface of the at least one actuator apparatus engages the one or more support surface units.

[0049] The present invention further provides a transmission system, the transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes rotation of the output, the first pulley comprising:

a first side assembly and a second side assembly spaced from each other, the first side assembly and second side assembly are co-axially mounted and rotatably fixed together;

an annular recess between the first side assembly and second side assembly, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley at a first diameter;

each of the first side assembly and second side assembly comprising a support surface comprising a plurality of independently mounted support surface units adapted to engage the cable, each support surface unit being laterally movable between at least a first position, wherein the cable is at a first diameter, and a second position, wherein the cable is at a second diameter, the second position being spaced inwardly from the first position.

[0050] The present invention further provides a transmission system, the transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes rotation of the output, the first pulley comprising:

a first side assembly and a second side assembly spaced from each other, the first side assembly and second side assembly are co-axially mounted and rotatably fixed together;

an annular recess between the first side assembly and second side assembly, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley;

each of the first side assembly and second side assembly comprising a support surface, the support surface comprises a plurality of support surface units, each support surface unit being movable relative to each other, the support surface is laterally movable, the support

surface is selectively movable between at least a first position and a second position, the second position being spaced inwardly from the first position, wherein all or any part of the support surface can be in the first position or the second position, the support surface being adapted to engage the cable wherein when the entire support surface of each side assembly is in the first position the cable is supported at a first diameter of the first pulley, when the entire support surface of each side assembly is in the second position the cable is supported at a second diameter, when a first portion of the support surface of each side assembly is in the first position, and a second portion of the support surface is in the second position the cable is supported on the first pulley which is at a third diameter, the third diameter being a diameter between the first diameter and the second diameter.

[0051] The support surface may be selectively positioned such that the third diameter is any sized diameter between the first diameter and the second diameter. The first diameter may be the smallest diameter possible for the first pulley. The second diameter may be the largest diameter possible for the first pulley.

[0052] The movement of the support surface of the first side assembly between the first position and second position may be just after or just before the movement of the support surface of the second side assembly between the first position and second position.

[0053] Each support surface unit may be laterally movable between at least a first position and a second position. The first side assembly may be connected to the second side assembly. The plurality of support surface units may co-operate to provide the support surface whereby selective movement of the support surface units causes the cable to transition to be positioned between different diameters of the first pulley.

[0054] The first side assembly and the second side assembly may be co-axially mounted.

[0055] Preferably during movement of each of the support surface units from the first position to the second position the cable is supported on the first pulley which is presenting a constantly increasing diameter.

[0056] Preferably during movement of each of the support surface units from the second position to the first position the cable is supported on the first pulley which is presenting a constantly decreasing diameter.

[0057] Preferably the support surface comprises a plurality of support surface segments wherein each support surface segment provides one or more support surface units. The support surface segments may take the shape of a pie segment, such that the combined configuration of the plurality of support surface segments is circular.

[0058] Each support surface unit provides at least one contact surface adapted to engage the cable. Each contact surface extends laterally from the support surface unit in a generally central direction. That is to say that each contact surface of each support surface unit extends

towards a central plane of the first pulley wherein the central plane is substantially perpendicular to the pulleys axis of rotation.

[0059] Preferably the contact surfaces of the first side assembly are offset from corresponding contact surfaces of the second side assembly.

[0060] The contact surfaces of the first side assembly may be offset from corresponding contact surfaces of the second side assembly such that the contact surfaces of the first side assembly may be at a different diameter/radial position to corresponding contact surfaces of the second side assembly.

[0061] The contact surfaces of the first side assembly may be offset from corresponding contact surfaces of the second side assembly such that when the contact surfaces of the first side assembly are in the second position and the contact surfaces of the second side assembly are in the second position, the contact surfaces overlap.

[0062] Preferably movement of each of the support surface units to the second position causes a portion of the contact surface of the first side assembly to be received between radially adjacent contact surfaces of the second side assembly. With this arrangement the support surface units effectively mesh together to provide a substantially continuous recess for supporting the cable.

[0063] The first pulley may comprise a support cradle for supporting the cable when the cable is at a position corresponding to the smallest possible diameter of the first pulley.

[0064] In one aspect of the invention the support cradle is fixed. The support cradle may be in the form of one or more support surface units fixed in the second position.

[0065] In another aspect of the invention the support cradle may be movable. The support cradle may be provided by the innermost support surface units wherein the innermost support surface units are prevented from moving to their first position, instead being movable between an intermediate position and the second position, the intermediate position being between the first position and the second position. The backing plate may also comprise a cradle portion which forms part of the support cradle.

[0066] The cable may connect the first pulley and the output. The cable may extend between the first pulley and the output such that the cable loops partially around the pulley and partially around the output.

[0067] The cable may be in the form of a continuous belt which frictionally engages the first pulley. The cross section of the belt may be V-shaped, and may be truncated.

[0068] The cable may have a face which is adapted to be supported by the support surface of each of the first side assembly and second side assembly, wherein the cross section of the belt is V-shaped, and may be truncated. Preferably at least 50% of the vee-shaped face is

supported by the support surface. Preferably at least 75% of the vee-shaped face is supported by the support surface. Preferably at least 80% of the vee-shaped face is supported by the support surface. Preferably at least 85% of the vee-shaped face is supported by the support surface.

[0069] The belt may comprise a plurality of wedge shaped segments depending from a belt portion. Preferably the cross sectional profile of the belt changes between a tensioned state wherein the profile represents a narrow V-shape, and a relaxed state wherein the profile represents a broader V-shape. The belt may adopt the tensioned state when it spans between the pulley and the output. The belt may adopt the relaxed state when the belt engages the pulley and when the belt engages the output. When the belt is in the relaxed state the broader V-shaped cross section presents a greater surface area to engage the annular recess of the pulley, and the output. In this regard the V-shape complements the annular recess. When in the tensioned state the narrower V- shape presents a reduced surface area such that the cross section is narrower than the cross section of the annular recess. As a result the belt does not engage with the pulley until further around the pulley, and disengages from the pulley earlier than if the belt only had one state. This configuration reduces friction losses encountered at the transition of the belt engaging and disengaging from the pulley.

[0070] In one aspect of the invention the frictional forces between the belt and the pulley are the same when considered from all directions.

[0071] In another aspect of the invention the ratio of the friction between the belt and the pulley in the belt driving direction to the friction between the belt and the pulley in a direction at or near normal to the driving direction is as high as possible, being higher than 1:1, in that the driving direction friction is lower than the normal friction. When friction between the belt and the pulley in the belt driven direction is high, and the friction between the belt and the pulley in a direction normal to the driven direction is low, power transmission is possible without belt slip. It also allows for improved shifting of gearing to overcome non-drive directional friction between belt and pulley.

[0072] In one aspect of the invention the surface of the belt and/or the surface of the pulley may comprise surface irregularities such as projections and/or knurls, to increase friction between the belt and the pulley.

[0073] In another aspect of the invention the surface of the belt and/or the surface of the pulley may comprise surface irregularities such as projections, knurls, grooves, and/or patterns to assist in increasing the ratio of the friction between the belt and the pulley in the belt driving direction to the friction between the belt and the pulley in a direction at or near normal to the driving direction.

[0074] The cable may be in the form of a composite material. The cable may have a core. The core may be formed from a non-yielding material such as aramid or carbon fibre. While the core is flexible the length of the core, once formed into the belt, does not significantly yield.

[0075] Preferably the output is in the form of a second pulley. The second pulley may be a smaller, or larger, version of the first pulley. The second pulley may comprise a first side assembly and a second side assembly spaced from each other, the first side assembly being connected to the second side assembly such that the first side assembly and second side assembly are co-axially mounted. Preferably each of the first side assembly and second side assembly of the second pulley comprise a support surface.

[0076] In one aspect of the invention the first pulley comprises an activation means to cause movement of the support surface units of each side assembly between the first position and the second position. Using the activation means the first pulley controls the position of the cable, effectively determining the gearing of the transmission system. Preferably the second pulley reacts to the movement of the at least one ring of each side assembly of the first pulley. In this regard the second pulley is a passive pulley.

[0077] In another aspect of the invention the second pulley comprises an activation means to cause movement of the at least one ring of each side assembly between the first position and the second position. Using the activation means the second pulley controls the position of the cable, effectively determining the gearing of the transmission system. Preferably the first pulley reacts to the movement of the support surface units of each side assembly of the second pulley.

[0078] The activation means may comprise at least one guide means wherein the at least one guide means selectively moves the support surface units between the first position and the second position.

[0079] The at least one guide means may be provided by at least one actuator apparatus. The at least one actuator apparatus may comprises a first actuator head and a second actuator head held in fixed relation. Each actuator head may provide the at least one guide means.

[0080] The at least one guide means may be in the form of a first guide means and a second guide means. The first guide means may cause the support surface to move to the second position. The first guide means may comprise a first guide surface which engages each support surface unit of the support surface.

[0081] The second guide means may guide the support surface to the first position. The second guide means may comprise a second guide surface which causes the support surface to move to the first position. The second guide surface may comprise an actuator channel which cooperates with a portion of each support surface unit to cause the support surface to move to the first position.

[0082] The activation means may comprise a control means to control the movement of the at least one actuator apparatus. The control means may constrain the at least one actuator apparatus such that the at least one actuator apparatus is limited to radial movement relative to each side assembly.

[0083] Preferably the transmission system is arranged such that as the first pulley moves from the first diameter to the second diameter, the second pulley moves from the second diameter to the first diameter. As the belt is fixed in length, the belt must move relative to the second pulley in order to compensate for movement of the belt relative to the first pulley. Therefore, as the belt is positioned to rotate about the larger second diameter of the first pulley, the belt is caused to move to rotate about the smaller first diameter of the second pulley or vice versa.

[0084] The present invention further provides a transmission system, the transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes rotation of the output, the first pulley comprising:

a first side assembly and a second side assembly spaced from each other, the first side assembly and second side assembly are co-axially mounted and rotatably fixed together;

an annular recess between the first side assembly and second side assembly, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley;

each of the first side assembly and second side assembly comprising a support surface provided by a plurality of rings wherein the rings on the first side assembly are at different diameters to the rings on the second side assembly, and the rings on the second side assembly have an offset corresponding ring on the first side assembly wherein corresponding rings move between at least a first position and a second position, the second position being spaced inwardly from the first position, corresponding rings being adapted to engage the cable wherein when the corresponding rings are in the second position the cable is supported by the first pulley at a different diameter to the diameter defined by the adjacent corresponding rings, each ring comprises a plurality of support surface units, each support surface unit of each ring being independently movable by at least one actuator apparatus.

[0085] The present invention provides a transmission system, the transmission system comprising a first pulley connected to an output by a cable such that movement of the first pulley causes rotation of the output, the first pulley comprising:

an annular recess between a first side of the first pulley and a second side of the first pulley, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley;

a pair of support surfaces located in the annular recess, the pair of support surfaces being moveable in a lateral direction relative to the sides of the pulley between a spaced condition,

wherein the first pulley is at a first diameter and the pair of support surfaces do not engage the cable, and a meshed condition, wherein the first pulley is at a second diameter and the pair of support surfaces support the cable, the second diameter being larger than the first diameter.

[0086] The present invention provides a variable diameter pulley, the pulley comprising:

an annular recess for receiving a cable such that the cable is supported by the pulley at a first diameter of the pulley;

a pair of support surfaces located in the annular recess, the pair of support surfaces being moveable in a lateral direction between a spaced condition, wherein the pair of support surfaces do not engage the cable, and a meshed condition, wherein the pair of support surfaces support the cable at a second diameter of the pulley, the second diameter being larger than the first diameter.

[0087] The present invention provides a variable diameter pulley, the pulley comprising:

an annular recess adapted to receive a cable at a first diameter of the pulley;

the annular recess providing a support surface for supporting the cable when received therein, the support surface being movable to present the first diameter and a second diameter;

wherein the support surface is positionable to present any diameter between the first diameter and the second diameter.

[0088] Preferably the support surface presents a substantially continuous surface to the cable when received on the pulley. The cross sectional profile of the support surface may be complementary to the cross sectional shape of that portion of the cable which engages the support surface so that the cable is retained in the annular recess.

[0089] Preferably as the support surface moves between the first diameter and the second diameter, the cable, when supported thereon, remains in the same radial plane.

[0090] Preferably the support surface is formed from a first set of support surface units and a second set of support surface units, each support surface unit being movable relative to each other.

[0091] The first set of support surface units and the second set of support surface units may mesh together or overlap with each other to form the support surface.

[0092] The first set of support surface units and the second set of support surface units may be moveable in a lateral direction between a spaced condition, wherein the cable may be supported at the first diameter pf the pulley, and a meshed condition, wherein the cable may be supported at the second diameter of the pulley, whereby during movement of the set of support

surface units between conditions the cable may be supported on the support surface which is presenting a changing diameter.

[0093] Circumferentially adjacent support surface units may define a ring. Each ring may not be continuous. Preferably a gap is defined between adjacent support surface units of the same ring.

[0094] Each ring of the first set of support surface units has a complementary ring of the second set of support surface units, whereby complementary rings are in a staggered relation to each other to provide a ring pair. Meshing of each ring pair provides the support surface for engaging the cable.

[0095] Each ring pair may move between a first position and a second position.

[0096] In the first position the complementary rings of a ring pair may be spaced away from each other in the axial/lateral direction. In this position the cable cannot be supported by the ring pair.

[0097] In the second position the complementary rings of the ring pair may be in the meshed condition to provide the support surface. In this position the cable is supported by the ring pair.

[0098] Each ring pair may move to a third position which is between the first position and the second position.

[0099] Each ring of support surface units may be arranged so that as a ring approaches the second position the adjacent upper/outer ring thereto commences moving towards the second position.

[00100] Each ring of each set of support surface units may be arranged so that as a ring approaches the first position the adjacent lower/inner ring thereto commences its movement towards the first position.

[00101] Each support surface unit may be wedge shaped to provide a sloped contact surface which engages the cable.

[00102] The pulley may comprise a first side housing for housing the first set of support surface units. The pulley may comprise a second side housing for housing the second set of support surface units.

[00103] The first side housing and the second side housing may be co-axially mounted with respect to each other to define the annular recess therebetween.

[00104] The pulley may comprise activation means to cause movement of the ring pairs between the first position and the second position.

[00105] The activation means may comprise a plurality of actuator apparatus. Each actuator apparatus may be movable in a radial direction between a first position, central of the pulley and

a second position, adjacent the outer diameter of the pulley. Each actuator apparatus may have at least one head adapted to cause movement of the support surface units as each actuator apparatus moves between positions. Preferably each actuator apparatus has a first head, adapted to cause movement of the support surface units of the first side assembly, and a second head, adapted to cause movement of the support surface units of the second side assembly as each actuator apparatus moves between positions.

[00106] The first head and second head may be interconnected by a bridge extending therebetween such that they are held in fixed relation to each other.

[00107] Each actuator apparatus is supported in corresponding channels in the first side housing and second side housing. The plurality of actuator apparatus may be spaced from each other radially in a spider web type arrangement.

[00108] As the first head and second head of the actuator apparatus move from their first position towards their second position they cause the support surface units to successively move from their first position to their second position.

[00109] Preferably as and after the heads of each actuator apparatus successively engages each support surface unit when moving in a radially outward direction each support surface unit moves to its second position.

[00110] Preferably as and after the heads of each actuator apparatus successively pass each support surface unit when moving in a radially inward direction each support surface unit moves back to its first position.

[00111] The activation means may be manually activated or automatically activated.

[00112] In one aspect of the invention the activation means may be activated mechanically as a result of an input force from an operator.

[00113] In another aspect of the invention the activation means may be activated by a motor wherein the motor is adapted to cause movement of the actuator apparatus.

[00114] In another aspect of the invention the activation means further comprises a control means. The control means may provide a guide plate. Preferably, each set of support surface units has a guide plate which is rotatable relative thereto. Each end of the actuator apparatus incorporates a rotatable wheel, wherein the wheel is received in a guide of the guide plate. The guide may be spiral in configuration such that as the guide plate rotates each wheel rotates around the spiral guide. Preferably rotation of the guide plate causes the actuator apparatus to move in a radial direction dictated by the radial channels incorporated in each of the first housing and the second housing, wherein movement of the actuator apparatus causes movement of the support surface units between the first position and the second position.

[00115] The present invention provides a transmission system, the transmission system comprising a variable diameter pulley as herein before described connected to an output by a belt such that movement of the pulley causes rotation of the output, the activating means being activated by a motor wherein the motor is powered by a power supply located within the spatial foot print of the transmission system, such as for example, in the crank arm or inside the spindle. The power supply may be recharged through a charging socket, eliminating the need to remove the battery for re-charging.

BRIEF DESCRIPTION OF THE DRAWINGS

[00116] Further features of the present invention are more fully described in the following description of a non-limiting embodiment thereof. This description is included solely for the purposes of exemplifying the present invention. It should not be understood as a restriction on the broad summary, disclosure or description of the invention as set out above. The description will be made with reference to the accompanying drawings in which:

Figure 1 is a side view of a front pulley assembly of a transmission system of a bicycle according to a first embodiment of the invention;

Figure 2 is a perspective view of the first pulley of figure 1;

Figure 3 is a side view of figure 2;

Figure 4 is a view similar to figure 3 with a side housing removed;

Figure 5 is a partial exploded view of figure 3 with the housing and a backing plate from one side being in an exploded format;

Figure 6 is a view similar to figure 5 with the housing and the backing plate from one side removed;

Figure 7 is a partial exploded view of figure 3 with the housing, the backing plate and a support surface from one side being in an exploded format;

Figure 8 is an exploded front view of the first pulley shown in figure 3;

Figure 9 is a view similar to figure 8 with the housing, the backing plate and the support surface from one side removed;

Figure 10 is a side view of figure 9;

Figure 11 is a view similar to figure 10 with a plurality of actuator apparatus removed;

Figure 12 is a perspective view of one side of the first pulley and plurality of actuator apparatus shown in an exploded view;

Figures 13 to 15 (a, b) are various views of support surface units;

Figure 16 (a, b, c) are various views of one of the support surface units shown in figures 13 to 15;

Figure 17 (a,b) is a close up view of one support surface unit engaging an adjacent support surface unit;

Figure 18 is a perspective view of an actuator apparatus without guide wheels'

Figure 19 is a perspective view of a plurality of actuator apparatus;

Figure 20 is a perspective view of a two actuator apparatus supporting one support surface unit;

Figure 21 is a cut away section of the first pulley;

Figure 22 is a perspective view of a guide plate of an activation means;

Figures 23, 24, 25 are side views of figure 22 wherein the guide plate is at a different angular position to show movement of the plurality of actuator apparatus;

Figure 26 is a cross sectional perspective view of the first pulley taken through a vertical plane;

Figure 27 is an end view of figure 26;

Figure 28 is a close up view of the upper section of figure 26;

Figure 29 is a schematic representation of an end view of figure 28

Figure 30 is a schematic representation of the transmission system of the first embodiment when at the smallest/lowest gear ratio (one side of each pulley being removed for illustrative purposes);

Figures 31 to 34 are various schematic representations of a section of the first pulley showing the position of the plurality of support surface units of the pulley of figure 30 when supporting the cable at its lowermost position, representing the smallest diameter;

Figures 35 and 36 are schematic representations of a section of the first pulley showing the change in position of the plurality of support surface units as the actuator apparatus begins to move outwardly relative to the central region of the first pulley;

Figures 37 and 38 are schematic representations of a section of the first pulley showing the change in position of the plurality of support surface units as the actuator apparatus continues to move outwardly relative to the central region of the first pulley;

Figures 39 and 40 are schematic representations of a section of the first pulley showing the change in position of the plurality of support surface units as the actuator apparatus further continues to move outwardly relative to the central region of the first pulley;

Figures 41, 42 and 43 are schematic representations of the transmission system (one side of each pulley being removed for illustrative purposes) and a section of the first pulley showing the

change in position of the plurality of support surface units as the actuator apparatus approaches its outermost position relative to the central region of the first pulley;

Figures 44 and 45 are schematic representations of the transmission system (one side of each pulley being removed for illustrative purposes) and a section of the first pulley showing the change in position of the plurality of support surface units as the actuator apparatus is at its outermost position relative to the central region of the first pulley;

Figure 46 (a, b, c, d) are schematic representations of a section of the first pulley showing the change in position of the plurality of support surface units as the actuator apparatus returns to its lowermost position;

Figure 47 is a perspective view of the backing plate of figure 5; and

Figure 48 is a schematic view of the first pulley with crank arm and a motor positioned therein.

DESCRIPTION OF EMBODIMENTS

[00117] The present invention according to a first embodiment of the invention, as depicted in the figures, is in the form of a transmission system 12 comprising a first variable diameter pulley 11. The pulley 11 is particularly adapted for use with a transmission system which functions in a similar/same manner as a continuously variable transmission (CVT).

[00118] As will be highlighted in the below discussion, a difference between the present invention and CVT's of the prior art is that the pulley of the present invention is configured to maintain a relatively narrow gauge. This enables the pulley and associated transmission system to be used in applications which have minimal space for a transmission system, such as, for example, bicycles including conventional bicycles, e-bicycles and pedelecs.

[00119] Previous CVT's comprise relatively thick front and/or rear pulley arrangements which could not be readily utilised in applications which have limited space to house the pulley arrangement. For example, prior art CVTs could not be applied to bicycles as it would impede the pedal action, not provide a sufficient range in gear ratios, place significant stress on the chain and/or are too heavy. The relatively narrow pulley of the present invention provides the transmission system with a practical and efficient drive train geometry. When applied to a bicycle the thickness of the pulley of the present invention is similar to the thickness of a crank set of a conventional bicycle with two or more chain rings.

[00120] The present invention also allows the diameter of the pulley to be increased with minimal or no change in the width of the pulley. This provides for a large range of gear ratios. This further enhances the vast array of applications the present invention is suited.

[00121] The below embodiment discuss the present invention as applied to a bicycle. However, there are many more applications in other types of driven equipment. These include applications in vehicles, lawnmowers, motorised scooters, quad-bikes, snowmobiles, mobile or

industrial equipment such as generators, turbines, conveyors and chainsaws. These other applications, and similar, are considered to be within the scope of this invention.

[00122] In the present embodiment the pulley 11 is adapted to support two crank arms 13 to which pedals/clips 15 are secured. A rider (not shown) can engage pedals 15 to cause the pulley 11 to rotate, this arrangement being well known.

[00123] In this embodiment the pulley 11 is secured to a frame of the bicycle (not shown) so that the pulley 11 is located adjacent the frame. The pulley 11 comprises a first side assembly 17 and a second side assembly 19. The first side assembly 17 and the second side assembly 19 are co-axially mounted.

[00124] One of the crank arms 13a is connected to a shaft or spindle which passes through a bottom bracket of the bicycle frame before being secured relative to the second side assembly 19. The second crank arm 13b is secured directly to an outer surface of the first side assembly 17.

[00125] The first side assembly 17 and the second side assembly 19 are spaced a distance from each other such that when the pulley 11 is assembled the first side assembly 17 and second side assembly 19 define an annular recess 25 therebetween. The annular recess 25 being adapted to receive a cable in the form of a v-shaped belt 40, as best shown in figure 32.

[00126] Each side assembly 17, 19 comprise a housing 27, a backing plate 29 and a support surface 31. As the configuration of the second side assembly 19 is largely identical to that of the first side assembly 17, and for ease of reference, similar components of the side assemblies are suffixed with ‘a’ when associated with the first side assembly 17, and are suffixed with ‘b’ when associated with the second side assembly 19.

[00127] As best shown in figure 3, the annular recess 25 is defined by the housing 27a of the first side assembly 17, the housing 27b of the second side assembly 19 and the support surface 31. The support surface 31 are moveable in a lateral direction between a first/spaced condition, wherein the support surface 31 does not engage the belt 40, and a second/meshed condition, wherein the support surface 31 supports the belt 40 at a second diameter of the pulley, the second diameter being larger than the first diameter.

[00128] Each support surface 31 comprises a plurality of support surface units 33. When arranged the support surface units 33 are in a circular configuration divided into a plurality of support surface segments 35. Each support surface segment 35 has a gap 37 therebetween for reasons which will be described below.

[00129] As shown in figure 14, each support surface segment 35 comprises a set of the plurality of support surface units 33 arranged to be one on top of the other. In this embodiment each support surface segment 35 comprises one support surface unit 33 stacked on another support surface unit 33. In other embodiments each support surface segment 35 may have two

or more support surface units 33 in a side by side relation, with one or more support surface segments 35 stacked thereon.

[00130] Each support surface unit 33 provides a contact surface 39 which, when in position extends at a sloped orientation towards a central plane of the pulley. The contact surface 39 co-operates with the contact surface 39 of other support surface units 33 to provide the support surface 31 which directly engages and supports a cable in the form of a v-shaped belt 40, as will be described in further detail below.

[00131] An upper surface 41 of each support surface unit 33 is shaped to engage a complementary shape in a lower surface 43 of the adjacent support surface unit 33. As shown in figures 13 to 17 the complementary shape of the upper surface 41 and the adjacent lower surface 43 provide a spline type arrangement 45 whereby movement of adjacent support surface units 33 is restricted by the spline arrangement 45 to lateral movement with respect to each other, as depicted by arrow 'A' in figures 13 and 15.The lower surface 43 of each innermost support surface unit 33c also engages with the backing plate 29a, 29b in the spline arrangement 45 to restrict lateral movement with respect to each other. Similarly the upper surface 41 of each outermost support surface units 33d engages with the backing plate 29 in the spline arrangement 45 to restrict lateral movement with respect to each other. Figure 47 shows the backing plate 29 along with splines 46, which cooperate with mating splines on the innermost support surface unit 33c, and outermost support units 33d.

[00132] The lower surface 43 of each support surface unit 33 also comprises a projection 47. While each upper surface 41 comprises an indent 49 for receiving the projection 47 of the adjacent support surface unit 33. As best shown in figures 16b) and 16c) the projection 47 and indent 49 are located at a position distal from the contact surface 39. When adjacent support surface units 33 are in a second position, the projection 47 is received in the indent 49 of the adjacent support surface unit 33. Figure 17 illustrates two adjacent support surface units coming together wherein the projection 47 of one support surface unit 33 is being received in the indent 49 of an adjacent support surface unit. The cooperation of the projection 47 and the indent 49 restricts the lateral movement of the lower support surface unit 33 such that the lower adjacent support surface unit 33 cannot return to a first position. Before the support surface unit 33 can return to the first position, the upper adjacent support surface unit 33 must first commence its return journey to the first position.

[00133] Each support surface unit 33 has a pin 51 at each end. The pin 51 is used to move the support surface unit 33 between the first position and the second position as described below.

[00134] Each support surface unit 33 also has a guide surface 53 at each end. The guide surface 53 is located between the pin 51 and the contact surface 39. In this embodiment the guide surface 53 is parallel to the contact surface 39.

[00135] Each support surface unit 33 is arcuate in shape whereby support surface units 33 in adjacent support surface segments 35 at the same diameter define a ring, the ring being discontinuous as a result of gaps 37.

[00136] The pin 51 is utilised to move the support surface unit 33 between the first position and the second position as described below.

[00137] The guide surface 53 is utilised to move the support surface unit 33 between the first position and the second position as described below.

[00138] The pulley 11 also comprises an activation means 57 to cause the support surface 31 to move between the first position and the second position.

[00139] The activation means 57 comprises a plurality of actuator apparatus 59 and a control means to control the movement of the actuator apparatus 59. Each actuator apparatus 59 is movable in a radial direction in relation to the pulley 11. As each actuator apparatus 59 moves radially outward, the support surface 31 is caused to move from the first position to the second position. As each actuator apparatus 59 moves radially inward, the support surface 31 is caused to move from the second position to the first position. The control means is also able to hold the actuator apparatus 59 at any location between their innermost position and outermost position relative to the backing plate 29a, 29b.

[00140] As best shown in figures 18, 19 and 20, each actuator apparatus 59 comprises a first head 61a and a second head 61b which are held in spaced relation by a bridge 63 extending therebetween.

[00141] Each head 61a, 61b provide a first guide means 65 to cause the support surface units 33 to move to the second position. The first guide means 65 comprises a first guide surface 67 which is adapted to glidingly engage the guide surface 53 of each support surface unit 33.

[00142] Each head 61a, 61b also provides a second guide means 69 to guide the support surface 31 to the first position. The second guide means 69 comprises a second guide surface 71 on each side of the head 61a, 61b which engages the pin 51 of each support surface unit 33 to move it to the first position. The second guide surface 71 is in the form of an actuator channel 73 which receives and cooperates with the pin 51 of the support surface unit 33 to move the support surface 31 to the first position.

[00143] The actuator channel 73 has a first opening 75 in an upper part of the head 61a, 61b which is of a sufficient width to receive the pin 51. As each actuator apparatus 59 moves radially outward, the pin 51 of each side of the support surface unit 33 is received in the respective first opening 75. Further outward movement of the actuator apparatus 59 results in the first guide surface 67 of the actuator apparatus 59 engaging the guide surface 53 of each support surface unit 33. At this point the support surface unit 33 is caused to move towards its second position. As the support surface unit 33 begins to move towards its second position the

pin 51 traces along the second guide surface 71 which, in this embodiment is in the form of a sloped wall. Once the support surface unit 33 has reached its second position the pin 51 enters a second opening 77.

[00144] In order to move the support surface unit 33 from the second position to the first position the actuator apparatus 59 is caused to move radially downward. As the actuator apparatus 59 approaches the support surface unit 33, the pin 51 is received in the second opening 77. Further downward movement of the actuator apparatus 59 results in the pin engaging the sloped wall of the second guide surface 71. This forces the support surface unit 33 to move from the second position to the first position. Once the actuator apparatus 59 has moved sufficiently downward so that the support surface unit 33 is in the first position, the pin 51 exits the actuator channel 53 through the first opening 75.

[00145] Each end of each actuator apparatus provides a spigot 79 upon which is mounted a rotatable wheel 81. The rotatable wheel assists in the smooth movement of the actuator apparatus 59 in the radial direction.

[00146] The control means also comprises a plurality of support channels 83 which restricts movement of the plurality of actuator apparatus 59 to movement in the radial direction. The plurality of support channels 83 are formed in each backing plate 29a, 29b, as best shown in figures 4 and 5. As shown in figure 4, each end of each actuator apparatus 59 is positioned in its respective support channel 83 such that the backing plate 29 is received between the side of the actuator head 61 and the wheel 81.

[00147] The control means further comprises a movement mechanism 85 which moves each actuator apparatus 59 along its support channel 83. In this embodiment the movement mechanism 85 is provided by a guide plate 87 which is formed integral with each housing 27a, 27b. As best shown in figure 22 the guide plate 87 provides a spiral groove 89 having closed ends and which extends from the inner periphery 91 to the outer periphery 93. The guide plate is rotatably mounted relative to the backing plate 29.

[00148] The groove 89 is adapted to receive the wheels 81 of each actuator apparatus 59 such that as the guide plate 87 rotates, the wheels 81 travel along the groove 89. However, as the support channel 83 in the backing plate 29 restricts the movement of each actuator apparatus 59 to movement in a radial extent, and as each actuator apparatus 59 is angularly fixed, rotation of the guide plate 87 can only translate to radial movement of each actuator apparatus 59.

[00149] As the groove 89 is a spiral, each actuator apparatus 59 must be placed at different positions along the spiral. If each actuator apparatus was identical then each actuator apparatus 59 would be at a different radius. This would mean that portions of the support surface at one diameter will be at the first position, others will be at the second position and others will be in between. In order to ensure the support surface 31 has a uniform diameter at

any point therealong (i.e. either all support surface units 33 at that diameter being in the first position, the second position or in between) the first guide means 65 and second guide means of each actuator apparatus need to be at substantially the same radius. To achieve this the spigot 79 is placed at different positions along the head 61a, 61b of each actuator apparatus 59, as best shown in figures 10 and 20.

[00150] Referring to figure 48, the control means 58 also comprises a motor 97 and a gearing system 99. The gearing system 99 is in operable engagement with the guide plate 87, activation of the motor 97 results in movement of the gearing system 99 which causes the guide plate 87 to rotate, causing the actuator apparatus 59 to move in a radial direction.

[00151] When considering the plurality of support surface units 33 which are in a circumferentially adjacent arrangement, the adjacent support surface units 33 are in a circular configuration having gaps 37 located therebetween. Each support surface unit 33 is movable in a lateral direction relative to its side assembly 17, 19, between the first position, wherein the support surface unit 33 is adjacent the backing plate 29a, 29b, and the second position wherein the support surface unit 33 is spaced away from the backing plate 29a, 29b.

[00152] The support surface units 33 are arranged so that support surface units 33a on one side are offset relative to the corresponding support surface units 33b on the other side. In this arrangement the support surface units overlap, when in the second position, to provide the support surface 31 to support a minimum of approximately 75% of the belt 40.

[00153] As shown in figures 31 to 34, the first pulley 11 comprises a support cradle 95 for supporting the belt 40 when the belt 40 is at a position corresponding to the smallest possible diameter of the first pulley 11. The support cradle 95 is in the form of support surface units 33c closest to the central axis of the pulley 11 (see figure 33) and a cradle portion 101 of the backing plate (see figure 29). When the belt 40 is supported by the support cradle 95, as shown in figure 33, the remaining support surface units are in their first position and the belt 40 is supported by the pulley 11 at the systems smallest diameter, as best represented by figure 32. In this embodiment the support surface units 33c move between their second position and an intermediate position. As shown in figure 33, the intermediate position of the support surface unit 33c on the right hand side of the figure is closer to the second position than that on the left hand side. As the actuator apparatus moves outwardly, as will be described below, the support surface unit 33c on the right hand side is caused to move to its second position followed by the support surface unit 33c on the left hand side.

[00154] While not shown in figure 33, when the belt is at the smallest diameter of the pulley, the cradle portion 101 of the backing plate also provides part of the support surface 31 supporting the belt 40.

[00155] As the actuation apparatus 59 can be set at any position between their innermost position and outermost position the location of the belt 40 can be supported by the pulley at any diameter between the smallest diameter and the largest diameter.

[00156] The first variable diameter pulley 11 can be combined with a second variable diameter pulley 111 to complete the transmission system 12. As can be noted in the figures, the belt 40, which is a continuous loop, extends between the two pulleys 11, 111 to transfer movement from the first pulley 11 to the second pulley 111.

[00157] The second pulley 111 acts as a slave pulley whereby it reacts to changes of the first pulley 11. In this regard the second pulley 111 is a smaller version of the first pulley 11.

[00158] Owing to the configuration of the plurality of support surface units 33 the pulley presents a substantially continuous support surface to the belt 40 as the belt 40 moves relative to the pulley 11 between the smallest diameter and the largest diameter. In the present embodiment approximately 75% of the belt 40 is supported the plurality of support surface units 33 at any one time.

[00159] Figures 30 to 46 show various views of the transmission system. The transmission system 12 comprises the first variable diameter pulley 11, and the second variable diameter 111 interconnected by the belt 40. The various views show the belt 40 at various positions of the transmission system 12 wherein the various positions correspond to various gear positions of a conventional bicycle chain driven derailleur system.

[00160] Referring to figures 30 to 34, the transmission system 12 is shown at a position relating to the smallest/lowest gear ratio wherein the actuator apparatus 59 are at their innermost position, whereby the first guide surface 67 of each actuator head 61a, 61b engages the guide surface 53 of the support surface unit 33. This is also represented by figure 23 which shows each actuator apparatus 59 at their most inner position possible. In this position the innermost support surface units 33a of the first side assembly 17 of the first pulley 11, and the innermost support surface units 33b of the second side assembly 19 of the first pulley 11 are each in their second position. When in this position the remaining support surface units 33 of the first pulley 11 are in their first position.

[00161] When the belt 40 is supported by the first pulley 11 in the smallest diameter, the belt 40 is supported by the second pulley 111 in the largest diameter, as shown in figure 30. In this position the outermost support surface units 33 of the first side assembly 17 of the second pulley 111, and the outermost support surface units 33 of the second side assembly 19 of the second pulley 111 are each in their second position, with the remaining support surface units 33 also in their second position.

[00162] As the head 61a, 61b of the actuator apparatus 59 of the first pulley 11 moves outwardly the pin 51 of the next adjacent support surface unit 33 enters the first opening 75 of

the actuator channel 73. Further outward movement causes the first guide surface 67 of the head 61a, 61b to engage the guide surface 53 of the support surface unit 33. At this point the support surface unit 33 starts to move towards its second position. Further outward movement of the actuator apparatus 59 will result in the support surface unit 33 reaching its second position. Once in this position the pin 51 is in alignment with, and able to exit the second opening 77 of the actuator channel 73, allowing the actuator apparatus 59 to continue its outward movement.

[00163] This sequence continues for subsequent adjacent support surface unit 33 as the actuator apparatus 59 are caused to move further outward.

[00164] Once the actuator apparatus 59 has passed the support surface unit, whereby the support surface unit 33 is in its second position, the projection 47 in the lower surface 43 of the support surface unit, aligns with and is received in the indent 49 of the upper surface 41 of the lower adjacent support surface unit. This retains the lower adjacent support surface unit in the second position until the actuator apparatus 59 returns inwardly and causes the upper adjacent support surface units to return to their first position. This co-operation ensures the support surface units remain in their second position and do not unintentionally return to their first position until caused to do so by the actuator apparatus 59.

[00165] Referring to figures 35 and 36, the transmission system 12 is shown at a first intermediary position. In these figures the actuator apparatus 59 have commenced movement in the radially outward direction. The support surface unit 33c on the right hand side has been moved to the second position, while the support surface unit 33c on the left hand side has moved further towards its second position. This has caused the support surface 31 to move outwardly to a larger diameter, causing the belt 40 to move also to that diameter.

[00166] Referring to figures 37 and 38, the transmission system 12 is shown at a second intermediary position. Referring to figures 39 and 40, the transmission system 12 is shown at a third intermediary position. Referring to figures 41 to 43, the transmission system 12 is shown at a fourth intermediary position. In these sets of figures the transmission system 12 moves away from the smallest/lowest gear ratio. This is achieved by activating the control means to cause the movement mechanism 85 to rotate and move the actuator apparatus 59 to move outwardly towards their outermost position.

[00167] When the belt 40 is supported by the first pulley 11 in any intermediary position, the second pulley 111 reacts so that the belt 40 is suitably supported.

[00168] Referring to figures 44 and 45, the transmission system 12 is shown at a position relating to the largest/highest gear ratio wherein each actuator head 61a, 61b is at its the outermost position. This is also represented by figure 25 which shows each actuator apparatus 59 at their most outermost position as possible. In this position the first guide surface 67 of

each actuator head 61a, 61b engages the guide surface 53 of the outermost support surface units 33d of each side assembly 17, 19. In this position all support surface units 33 are each in their second position to support the belt 40 at the largest diameter.

[00169] When the belt 40 is supported by the first pulley 11 in the largest diameter the configuration of the pulley ensures that the recess 25 which receives the belt limits the ability of the belt 40 to disengage from the pulley 11.

[00170] When the belt 40 is supported by the first pulley 11 in the largest diameter, the belt 40 is supported by the second pulley 111 in the smallest diameter, as shown in figure 44.

[00171] In this embodiment the second pulley 111 is a reactionary pulley wherein the operation of the second pulley 111 is dictated by the operation of the first pulley 11. As the first pulley 11 is actively caused to move to a new operative position by the activation means, the change in tension in the belt 40 causes the second pulley 111 to react to support the belt 40 in a new position.

[00172] In reverse operation, as shown in figure 46, the support surface units 33 of the first pulley 11 are caused to return to their first position. As the head 61a, 61b of the actuator apparatus 59 moves inwardly the pin 51 of the below adjacent support surface unit 33 enters the second opening 77 of the actuator channel 73. Further inward movement causes the pin 51 to engage the second guide surface 71. With further inward movement, the sloping face of the second guide surface 71 acts on the pin 51 to cause the support surface unit 33 to return to its first position. When the support surface unit 33 is in the first position the pin 51 aligns with the first opening 75 of the actuator channel 73 before exiting the actuator channel 73, allowing the actuator apparatus 59 to continue its inward movement.

[00173] This sequence continues for subsequent support surface unit 33 as the actuator apparatus 59 are caused to move further inward.

[00174] Similarly, the support surface units of the second pulley 111 are caused to move such that the belt 40 is supported at larger diameters.

[00175] As can be seen by the operation of the present embodiment, the transmission system 12 presents a substantially continuous support surface on both the first pulley 11 and the second pulley 111 as the transmission system moves between the largest/highest gear ratio and the smallest/lowest gear ratio. Furthermore, the control means is operable such that the actuator apparatus 59 may be positioned anywhere between their lowermost and outermost position (inclusive) and may be held in that position. As such the surface which supports the belts can be at any diameter between the largest diameter and smallest diameter.

[00176] Considering bicycles, prior art chain driven derailleur systems have been prone to mechanical malfunction or even failure. These include chains coming off sprockets or chain rings when bicycles are subject to shock (e.g. riders going through holes in the road or over

edges) or excessively aggressive gear change events. At best these failures lead to considerable inconvenience, distortion of race results, or at worst it leads to rider injury.

[00177] The reason why this malfunction or failure is possible is due to the design and construction of prior art derailleur driven cassette and chain ring systems which do not physically force the chain to be retained in place. The present invention is designed such that it is relatively impossible for the belt to come off the front or rear pulleys because no jockey wheels are in use and the edge perimeters of the pulleys physically constrain the belt under any load including shocks induced by road conditions. This increases the safety for the ride and, in competition, levels the playing field.

[00178] The present invention mitigates loss of power during gear ratio changes as it provides continuous power transmission during those gear ratio changes. This does not apply to derailleur systems or any other discrete gearing systems of prior art bicycles which suffer from loss of momentum during gear (chain ring or sprocket) changes

[00179] Loss of momentum is particularly significant for prior art derailleur systems when changing between chain rings requiring associated multiple sprocket (typically 3-4) changes in the cassette at the same time in order to avoid excessive gear ratio adjustments from the current setting.

[00180] The present embodiment can be activated by single trigger up or down shifting (using existing or dedicated handle bar mounted shifter hardware) on the front crank set. The rear wheel gearing adjusts automatically to the crank setting. Prior art derailleur drive trains require the rider to separately coordinate shifting of rear sprockets as well as front chain rings to achieve continuous gearing during up or down shifts which is not only inefficient as it leads to loss of momentum as between 3 and 4 gears have to be traversed when chain rings are changed, but it also places a strain on the riders in a state of fatigue or needing to respond to race situations without warning.

[00181] The present embodiment removes the manual coordination requirement of rear (cassette) and front (chain ring) changes making shifting much simpler. This is particularly desirable when riders are fatigued. The present embodiment also removes gear ratio duplication which exists in all prior art chain ring and cassette combinations, thereby simplifying the system further.

[00182] The present embodiment eliminates the need for drivetrain lubrication which reduces maintenance and does not compromise drive efficiency. The present embodiment also expands on the largest as well as the smallest gear ratios available from prior art derailleur systems.

[00183] As the present embodiment is continuously variable riders are no longer forced to use comparably energy sapping large gear steps inherent in prior art drive trains.

[00184] The efficiency of the present embodiment is superior to that of the prior art systems as traditional systems suffer from inefficiencies when using smallest sprockets and when using cross chain gear settings. The efficiency of the present embodiment ensures more rider energy input at the crank set arrive at the rear wheel.

[00185] Many of the abovementioned advantages of the present embodiment are also realised in one form or another in other applications/embodiments of the present invention. For example changing between gears is no longer associated with a loss of/drop in power as the gears change. The present invention allows for the smooth transition between gear ratios whereby the transfer of power is maintained at all times. It also allows gear changes at load.

[00186] The present invention provides a transmission system having a relatively narrow, fixed width, pulley which is capable of being designed to have near unlimited gear ratios. This is in contrast to current variable diameter pulley systems which must increase in width as gear ratios increase.

[00187] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

[00188] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a”, “an” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “comprise”, “comprises,” “comprising,” “including,” and “having,” or variations thereof are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[00189] When an element or layer is referred to as being “on”, “engaged to”, “connected to” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” “directly engaged to”, “directly connected to” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,”

etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[00190] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[00191] Spatially relative terms, such as “inner,” “outer,” “beneath”, “below”, “lower”, “above”, “upper” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

Claims

1. A transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes movement of the output, the first pulley comprising:

   a first side assembly spaced from a second side assembly, the first side assembly and second side assembly are rotatably fixed together;

   a variable annular recess defined between the first side assembly and the second side assembly, the annular recess being adapted to receive the cable;

   each of the first side assembly and the second side assembly providing a support surface for supporting the cable, the support surface is laterally movable between a first position and a second position, the first position being spaced outwardly from the second position, the support surface of the first side assembly and the support surface of the second side assembly co-operate to engage the cable when the support surface of each side assembly is in the second position, whereupon the cable moves from a first diameter to be supported at a second diameter;

   the support surface comprises a plurality of support surface units, define the support surface, each support surface unit may move relative to each other;

   wherein the width of the first pulley remains constant as the support surface moves between the first diameter and the second diameter, and vice versa.

2. The transmission system according to claim 1 further comprising at least one actuator apparatus for moving each support surface between the first position and the second position, wherein the at least one actuator apparatus is variably positioned along a radial extent of the first pulley.

3. The transmission system according to claim 1 or 2 wherein the at least one actuator apparatus comprising a first actuator and a second actuator connected therebetween by a bridge member.

4. The transmission system according to claim 3 wherein the bridge member maintains the first actuator and the second actuator in a fixed relation.

5. The transmission system according to claims 3 or 4 wherein the first actuator co-operates with the support surface of the first side assembly and the second actuator simultaneously co-operates with the support surface of the second side assembly to move each support surface between the first position and the second position.

6. The transmission system according to claim 3, 4 or 5 wherein at least one or both of the first actuator and the second actuator provides a first guide means to cause the support surface to move to the second position the first guide means comprise a first guide surface which engages the support surface.

7. The transmission system according to any one of claims 3 to 6 wherein at least one or both of the first actuator and the second actuator provide a second guide means to guide the support surface to the first position, the second guide means comprise a second guide surface which causes the support surface to move to the first position.

8. The transmission system according to claim 7 wherein the second guide surface comprise an actuator channel which cooperates with a portion of the support surface to cause the support surface to move to the first position.

9. The transmission system according to any one of claims 1 to 8 wherein the pulley comprises a control means to control the movement of the at least one actuator apparatus, wherein the control means constrains the at least one actuator apparatus such that the at least one actuator apparatus is limited to radial movement relative to each side assembly.

10. The transmission system according to claim 9 wherein the control means comprises at least one support channel which engages the at least one actuator apparatus to limit movement along the at least one support channel, the at least one support channel extends in a radial direction relative to each side assembly such that the at least one actuator apparatus is limited to radial movement relative to each side assembly the at least one actuator apparatus being variably positioned along the radial extent.

11. The transmission system according to claim 9 or 10 wherein the control means comprises a support housing which supports the at least one actuator apparatus, the support housing comprises a backing plate and a movement mechanism, the backing plate is located at a position between the support surface and the movement mechanism.

12. The transmission system according to claim 11 wherein the backing plate incorporates the at least one support channel for restricting the movement of the at least one actuator apparatus to a radial direction.

13. The transmission system according to claim 11 or 12 wherein the movement mechanism causes the at least one actuator apparatus to move along the radial extent.

14. The transmission system according to claim 11, 12 or 13 wherein the movement mechanism comprises a guide plate which is rotatable relative to the backing plate, where rotation of the guide plate causes the at least one actuator apparatus to move along the at least one support channel of the guide plate.

15. The transmission system according to claim 14 wherein the movement mechanism comprises a motor and a series of gears which rotatably co-operate with the guide plate to move the at least one actuator apparatus along the radial extent.

16. The transmission system according to claim 14 or 15 wherein the guide plate is in the form of a scroll plate, the scroll plate comprises a spiral formation in the form of a groove which is of a spiral configuration.

17. The transmission system according to claim 16 wherein the groove is continuous from a first end adjacent an outer periphery of the guide plate to a second end adjacent an inner periphery of the guide plate.

18. The transmission system according to claim 16 or 17 wherein the spiral formation engages an end of the at least one actuator apparatus whereby rotation of the scroll plate will cause the end of the at least one actuator apparatus to move along the spiral, causing the at least one actuator apparatus to move along the at least one support channel in the backing plate.

19. The transmission system according to claim 14 or 15 wherein the guide plate incorporates at least one groove positioned to be in association with the at least one support channel of the backing plate, the at least one groove engages with an end of the at least one actuator apparatus,

20. The transmission system according to claim 19 wherein the at least one groove is angularly orientated relative to the at least one support channel such that rotation of the guide plate causes the at least one groove to move relative to the at least one support channel, the at least one actuator apparatus being forced to move by the at least one groove so as to move radially along the at least one support channel.

21. The transmission system according to any one of claims 1 to 20 wherein the support surface comprises a plurality of support segments arranged in a circular configuration wherein the overall appearance of each support segment is that of a truncated pie segment, each support segment comprises a sub set of the plurality of support surface units.

22. The transmission system according to claim 21 wherein each support surface unit of each single support segment is stacked one on top of the other

23. The transmission system according to claim 22 wherein the support surface unit positioned closest to the rotational axis of the pulley is the smallest inner support surface unit, with each support surface unit thereafter increasing in length.

24. The transmission system according to any one of claims 21 to 23 wherein each support surface unit is restricted to axial movement relative to adjacent support surface units.

25. The transmission system according to any one of claims 21 to 24 wherein each support surface unit has a spline arrangement therebetween, wherein the spline arrangement prevents tangential movement between adjacent support surface units.

26. The transmission system according to any one of claims 21 to 25 wherein each support surface unit comprises a limiting mechanism to limit axial movement between adjacent support surface units, the limiting mechanism comprises a projection incorporated in each support surface unit wherein the projection is adapted to co-operate with a recess in an adjacent support surface unit, the limiting mechanism at least maintains the support surface units in the second position until the at least one actuator apparatus causes the support surface unit to move back to the first position.

27. The transmission system according to any one of claims 1 to 20 wherein each support surface comprises a plurality of support surface units.

28. The transmission system according to claim 27 wherein each support surface unit is independently movable between the first position and the second position, each support surface unit being restricted to movement between the first position and the second position.

29. The transmission system according to any one of claims 21 to 28 wherein each support surface unit is adapted to co-operatively engage the at least one actuator apparatus wherein the at least one actuator apparatus causes each support surface unit to move between the first position and the second position.

30. The transmission system according to any one of claims 21 to 29 wherein the first guide surface of the at least one actuator apparatus engages the one or more support surface units.

31. The transmission system according to any one of claims 21 to 30 wherein the second guide surface of the at least one actuator apparatus engages the one or more support surface units.

32. A transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes rotation of the output, the first pulley comprising:

    a first side assembly and a second side assembly spaced from each other, the first side assembly and second side assembly are co-axially mounted and rotatably fixed together;

an annular recess between the first side assembly and second side assembly, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley at a first diameter;

each of the first side assembly and second side assembly comprising a support surface comprising a plurality of independently mounted support surface units adapted to engage the cable, each support surface unit being laterally movable between at least a first position, wherein the cable is at a first diameter, and a second position, wherein the cable is at a second diameter, the second position being spaced inwardly from the first position.

33. A transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes rotation of the output, the first pulley comprising:

a first side assembly and a second side assembly spaced from each other, the first side assembly and second side assembly are co-axially mounted and rotatably fixed together;

an annular recess between the first side assembly and second side assembly, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley;

each of the first side assembly and second side assembly comprising a support surface, the support surface comprises a plurality of support surface units, each support surface unit being movable relative to each other, the support surface is laterally movable, the support surface is selectively movable between at least a first position and a second position, the second position being spaced inwardly from the first position, wherein all or any part of the support surface can be in the first position or the second position, the support surface being adapted to engage the cable wherein when the entire support surface of each side assembly is in the first position the cable is supported at a first diameter of the first pulley, when the entire support surface of each side assembly is in the second position the cable is supported at a second diameter, when a first portion of the support surface of each side assembly is in the first position, and a second portion of the support surface is in the second position the cable is supported on the first pulley which is at a third diameter, the third diameter being a diameter between the first diameter and the second diameter.

34. The transmission system according to claim 33 wherein the support surface is selectively positioned such that the cable is supported at any sized diameter between the first diameter and the second diameter.

35. The transmission system according to claim 33 or 34 wherein each support surface unit being laterally movable between at least a first position and a second position, the plurality of support surface units co-operate to provide the support surface whereby selective movement of the support surface units causes the cable to transition to be positioned between different diameters of the first pulley.

36. The transmission system according claim 35 wherein during movement of each of the support surface units from the first position to the second position the cable is supported on the first pulley which is presenting a constantly increasing diameter, and wherein during movement of each of the support surface units from the second position to the first position the cable is supported on the first pulley which is presenting a constantly decreasing diameter.

37. The transmission system according to claim 33 wherein the support surface comprises a plurality of support surface segments wherein each support surface segment provides one or more support surface units the support surface segments takes the shape of a pie segment, such that the combined configuration of the plurality of support surface segments is circular.

38. The transmission system according to claims 35, 36 or 37 wherein each support surface unit provides at least one contact surface adapted to engage the cable each contact surface extends laterally from the support surface unit in a generally central direction, the contact surfaces of the first side assembly are offset from corresponding contact surfaces of the second side assembly.

39. The transmission system according to claim 38 wherein movement of each of the support surface units to the second position causes a portion of the contact surface of the first side assembly to be received between radially adjacent contact surfaces of the second side assembly.

40. The transmission system according to any one of claims 33 to 40 wherein cable extends between the first pulley and the output such that the cable loops partially around the pulley and partially around the output.

41. The transmission system according to claim 40 wherein the cable is in the form of a continuous belt which frictionally engages the first pulley the cable has a face which is adapted to be supported by the support surface of each of the first side assembly and second side assembly, wherein the cross section of the belt is vee-shaped, and may be truncated.

42. The transmission system according to claim 41 wherein at least 75% of the vee-shaped face is supported by the support surface.

43. The transmission system according to claim 41 or 42 wherein the cross sectional profile of the belt changes between a tensioned state wherein the profile represents a narrow V-shape, and a relaxed state wherein the profile represents a broader V-shape the belt adopting the tensioned state when it spans between the pulley and the output, the belt adopting the relaxed state when the belt engages the pulley and when the belt engages the output.

44. The transmission system according to any one of the preceding claims wherein the output is in the form of a second pulley, the second pulley being a smaller, or larger, version of the first pulley.

45. The transmission system according to any one of claims 33 to 44 wherein the first pulley comprises an activation means to cause movement of the support surface units of each side assembly between the first position and the second position.

46. The transmission system according to claim 45 wherein the second pulley reacts to the movement of the at least one ring of each side assembly of the first pulley.

47. The transmission system according to claims 43 or 44 wherein the second pulley comprises an activation means to cause movement of the at least one ring of each side assembly between the first position and the second position, the first pulley reacting to the movement of the support surface units of each side assembly of the second pulley.

48. The transmission system according to claims 45 wherein the activation means comprises at least one guide means wherein the at least one guide means selectively moves the support surface units between the first position and the second position.

49. The transmission system according to claim 48 wherein the at least one guide means is provided by at least one actuator apparatus, the at least one actuator apparatus comprises a first actuator head and a second actuator head held in fixed relation.

50. The transmission system according to claim 59 wherein each actuator head provides the at least one guide means in the form of a first guide means and a second guide means.

51. The transmission system according to claim 50 wherein the first guide means causes the support surface to move to the second position, the first guide means comprising a first guide surface which engages each support surface unit of the support surface.

52. The transmission system according to claim 50 or 51 wherein the second guide means guides the support surface to the first position, the second guide means comprises a second guide surface which causes the support surface to move to the first position.

53. The transmission system according to claim 52 wherein the second guide surface comprises an actuator channel which cooperates with a portion of each support surface unit to cause the support surface to move to the first position.

54. The transmission system according to any one of claims 45 to 53 wherein the activation means comprises a control means to control the movement of the at least one actuator apparatus, the control means constrains the at least one actuator apparatus such that the at least one actuator apparatus is limited to radial movement relative to each side assembly.

55. The transmission system according to any one of claims 43 to 54 wherein the transmission system is arranged such that as the first pulley moves from the first diameter to the second diameter, the second pulley moves from the second diameter to the first diameter.

56. A transmission system, the transmission system comprising a first pulley and an output which is spaced therefrom, a cable extends between the first pulley and the output such that movement of the first pulley causes rotation of the output, the first pulley comprising:

a first side assembly and a second side assembly spaced from each other, the first side assembly and second side assembly are co-axially mounted and rotatably fixed together;

an annular recess between the first side assembly and second side assembly, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley;

each of the first side assembly and second side assembly comprising a support surface provided by a plurality of rings wherein the rings on the first side assembly are at different diameters to the rings on the second side assembly, and the rings on the second side assembly have an offset corresponding ring on the first side assembly wherein corresponding rings move between at least a first position and a second position, the second position being spaced inwardly from the first position, corresponding rings being adapted to engage the cable wherein when the corresponding rings are in the second position the cable is supported by the first pulley at a different diameter to the

diameter defined by the adjacent corresponding rings, each ring comprises a plurality of support surface units, each support surface unit of each ring being independently movable by at least one actuator apparatus.

57. A transmission system, the transmission system comprising a first pulley connected to an output by a cable such that movement of the first pulley causes rotation of the output, the first pulley comprising:

an annular recess between a first side of the first pulley and a second side of the first pulley, the annular recess being adapted to receive the cable such that the cable is supported by the first pulley;

a pair of support surfaces located in the annular recess, the pair of support surfaces being moveable in a lateral direction relative to the sides of the pulley between a spaced condition, wherein the first pulley is at a first diameter and the pair of support surfaces do not engage the cable, and a meshed condition, wherein the first pulley is at a second diameter and the pair of support surfaces support the cable, the second diameter being larger than the first diameter.

58. A variable diameter pulley, the pulley comprising:

an annular recess for receiving a cable such that the cable is supported by the pulley at a first diameter of the pulley;

a pair of support surfaces located in the annular recess, the pair of support surfaces being moveable in a lateral direction between a spaced condition, wherein the pair of support surfaces do not engage the cable, and a meshed condition, wherein the pair of support surfaces support the cable at a second diameter of the pulley, the second diameter being larger than the first diameter.

59. A variable diameter pulley, the pulley comprising:

an annular recess adapted to receive a cable at a first diameter of the pulley;

the annular recess providing a support surface for supporting the cable when received therein, the support surface being movable to present the first diameter and a second diameter;

wherein the support surface is positionable to present any diameter between the first diameter and the second diameter.

60. The pulley according to claim 58 or 59 wherein the support surface presents a substantially continuous surface to the cable when received on the pulley.

61. The pulley according to claim 58, 59 or 60 wherein the cross sectional profile of the support surface is complementary to the cross sectional shape of that portion of the cable which engages the support surface so that the cable is retained in the annular recess.

62. The pulley according to any one of claims 58 to 61 wherein as the support surface moves between the first diameter and the second diameter, the cable, when supported thereon, remains in the same radial plane.

63. The pulley according to any one of claims 58 to 62 wherein the support surface is formed from a first set of support surface units and a second set of support surface units, each support surface unit being movable relative to each other.

64. The pulley according to claim 63 wherein the first set of support surface units and the second set of support surface units are moveable in a lateral direction between a spaced condition, wherein the cable may be supported at the first diameter of the pulley, and a meshed condition, wherein the cable may be supported at the second diameter of the pulley, whereby during movement of the set of support surface units between the spaced condition and the meshed condition the cable is supported on the support surface which is presenting a changing diameter.

65. The pulley according to claim 64 wherein circumferentially adjacent support surface units define a discontinuous ring, wherein a gap is defined between adjacent support surface units of the same ring each ring of the first set of support surface units has a complementary ring of the second set of support surface units, whereby complementary rings are in a staggered relation to each other to provide a ring pair, whereupon meshing of each ring pair provides the support surface for engaging the cable.

66. The pulley according to claim 63, 64 or 65 wherein each support surface unit is wedge shaped to provide a sloped contact surface which engages the cable.

67. The pulley according to any one of claims 58 to 66 wherein the pulley comprises a first side housing for housing the first set of support surface units, a second side housing for housing the second set of support surface units, the first side housing and the second side housing being co-axially mounted with respect to each other to define the annular recess therebetween.

68. The pulley according to any one of claims 58 to 67 further comprising activation means to cause movement of the ring pairs between the first position and the second position, the activation means comprising a plurality of actuator apparatus which are movable in a radial direction between a first position, central of the pulley and a second position, adjacent the outer diameter of the pulley.

69. The pulley according to claim 68 wherein each actuator apparatus has a first head, adapted to cause movement of the support surface units of the first side assembly, and a second head, adapted to cause movement of the support surface units of the second side assembly as each actuator apparatus moves between positions, the first head and second head are interconnected by a bridge extending therebetween such that they are held in fixed relation to each other.

70. The pulley according to claim 68 or 69 wherein each actuator apparatus is supported in corresponding channels in the first side housing and second side housing, the plurality of actuator apparatus are spaced from each other radially in a spider web type arrangement.

71. The pulley according to claims 68, 69 or 70 wherein as and after the heads of each actuator apparatus successively engages each support surface unit when moving in a radially outward direction each support surface unit moves to its second position, and as and after the heads of each actuator apparatus successively pass each support surface unit when moving in a radially inward direction each support surface unit moves back to its first position.

72. The pulley according to any one of claims 68 to 71 wherein the activation means further comprises a control means which provides a guide plate, wherein each set of support surface units has a guide plate which is rotatable relative thereto.

73. The pulley according to claim 72 wherein each end of the actuator apparatus incorporates a rotatable wheel, wherein the wheel is received in a guide of the guide plate, the guide is spiral in configuration such that as the guide plate rotates each wheel rotates around the spiral guide, wherein rotation of the guide plate causes the actuator apparatus to move in a radial direction dictated by the radial channels incorporated in each of the first housing and the second housing, wherein movement of the actuator apparatus causes movement of the support surface units between the first position and the second position.

74. A transmission system, the transmission system comprising a variable diameter pulley according to any one of claim 58 to 73 connected to an output by a belt such that movement of the pulley causes rotation of the output, the activating means being activated by a motor wherein the motor is powered by a power supply located within the spatial foot print of the transmission system, such as for example, in the crank arm or inside the spindle.

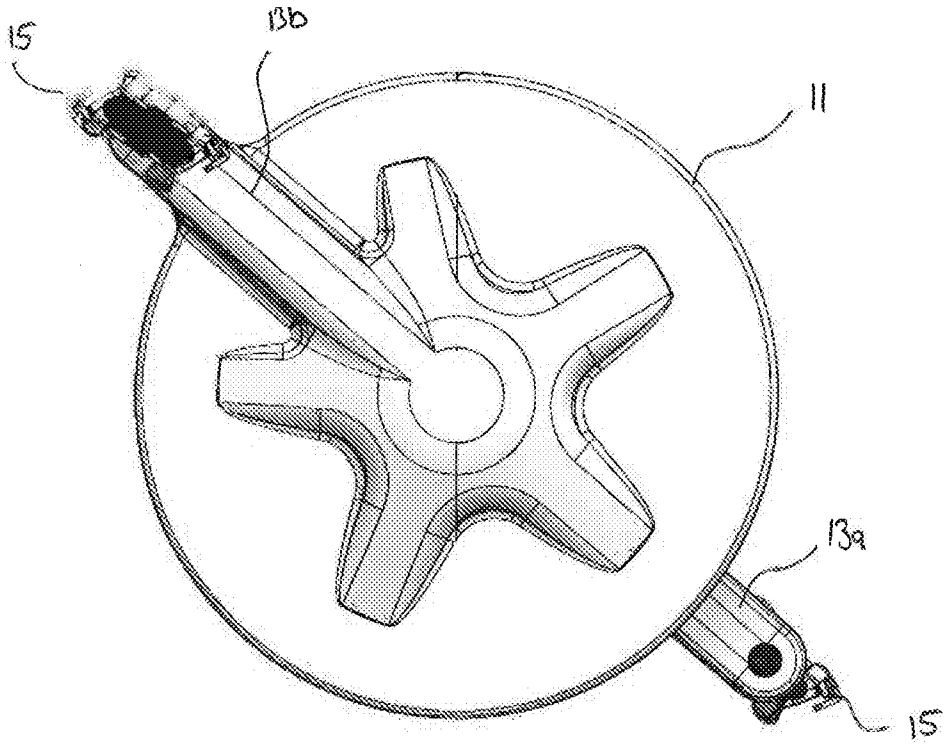


Figure 1

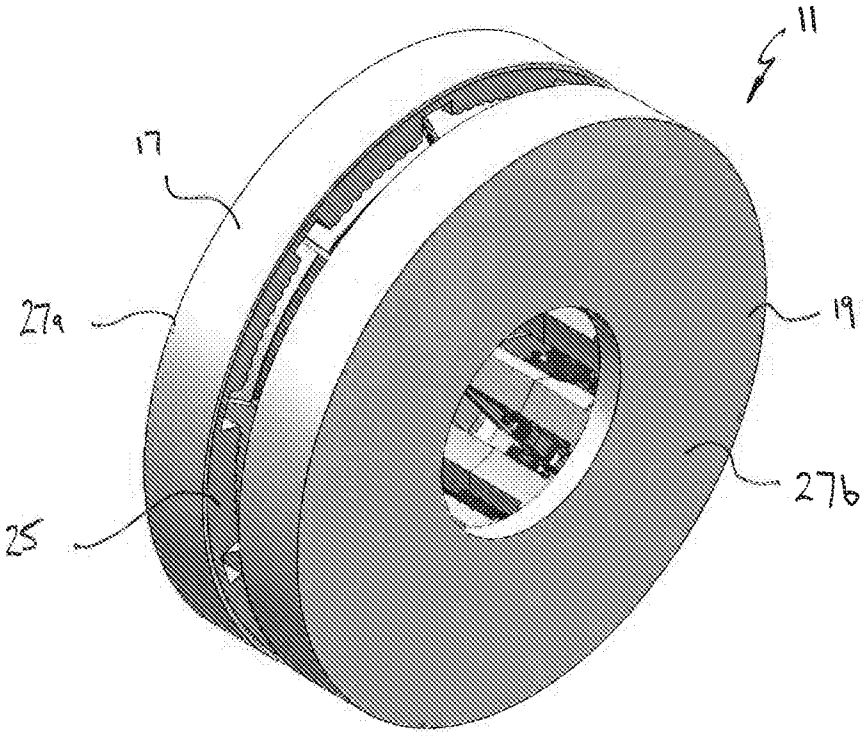


Figure 2

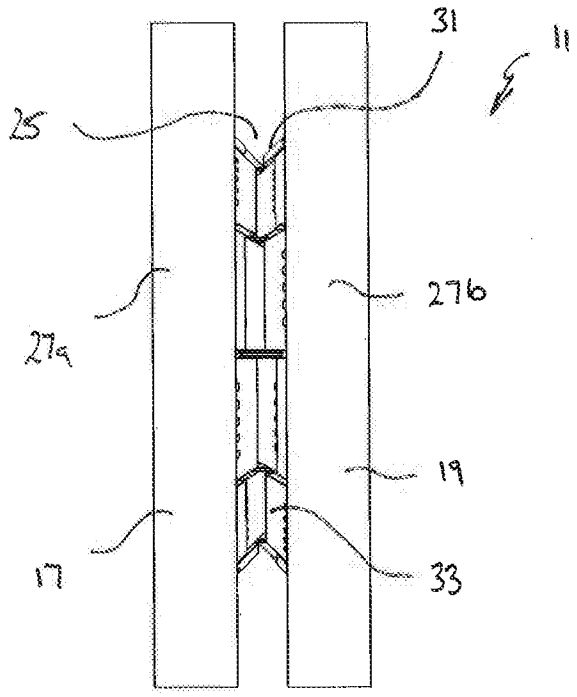
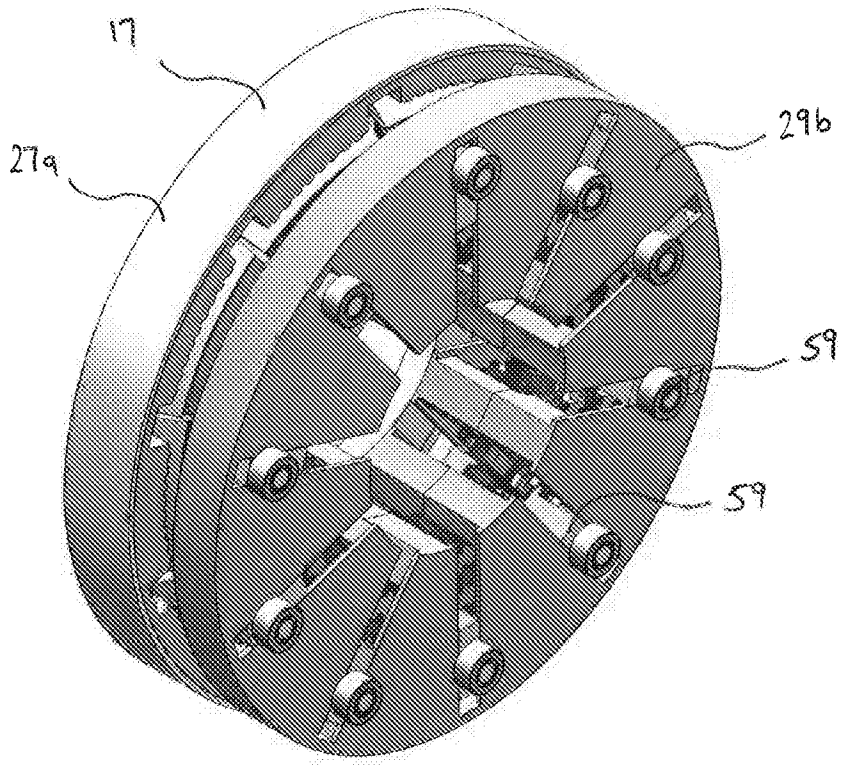


Figure 3



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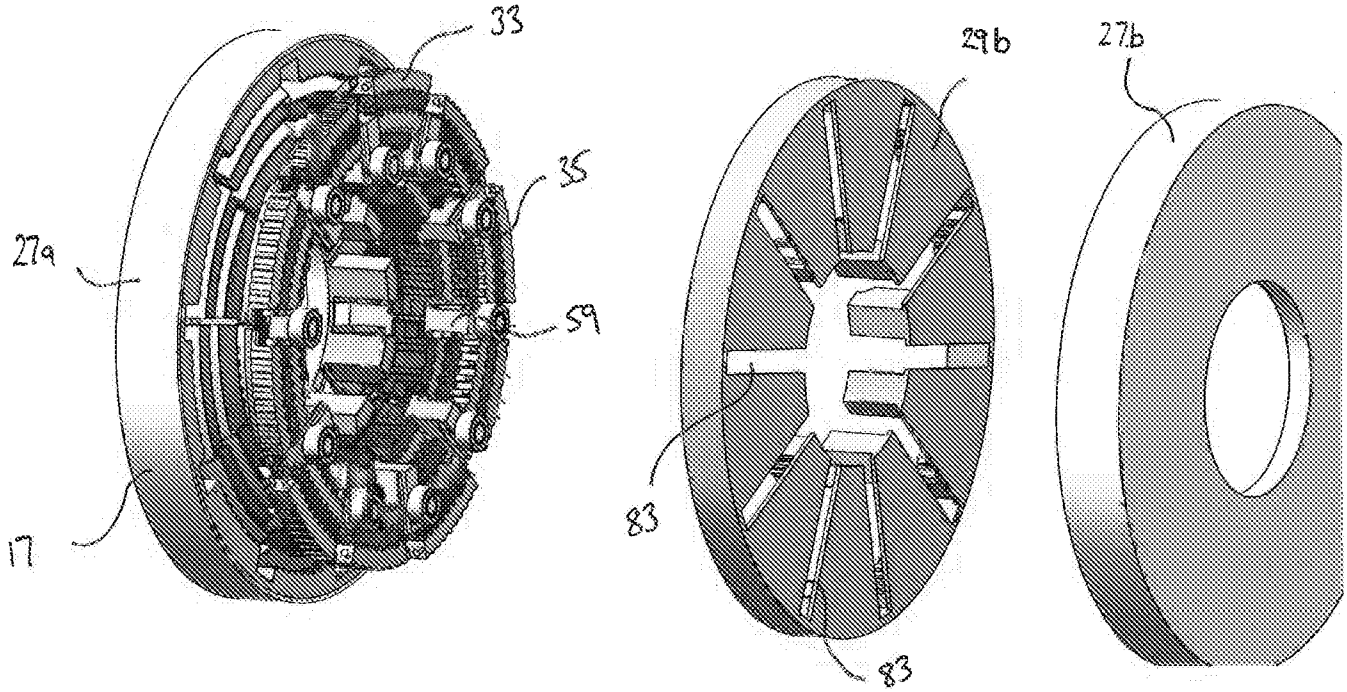
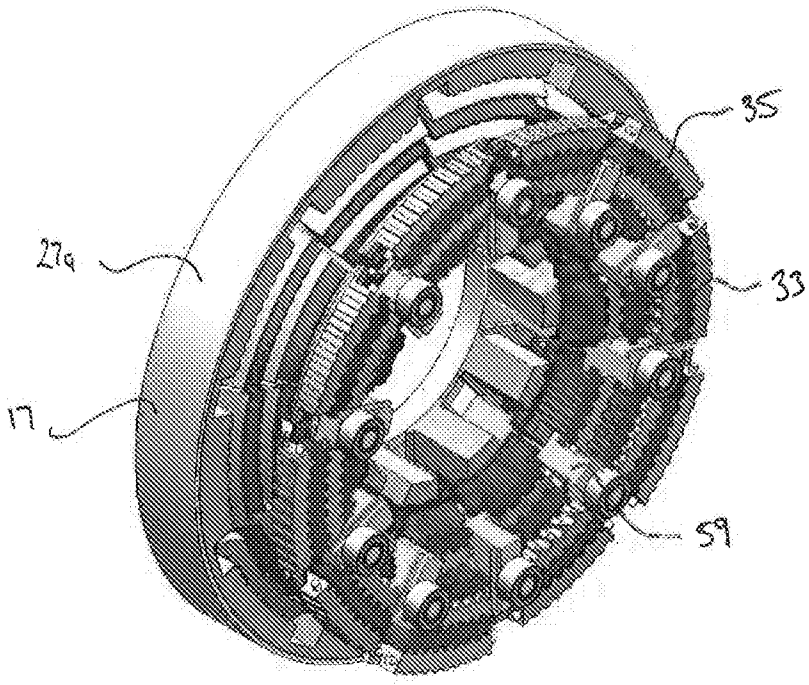


Figure 5



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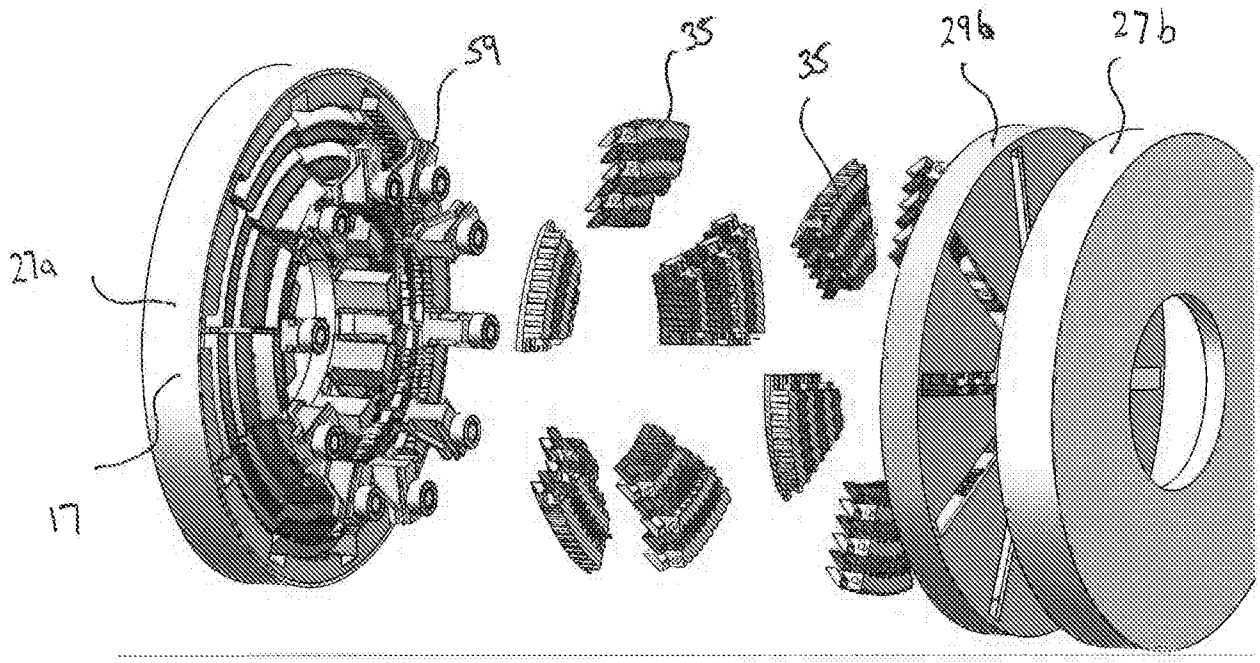

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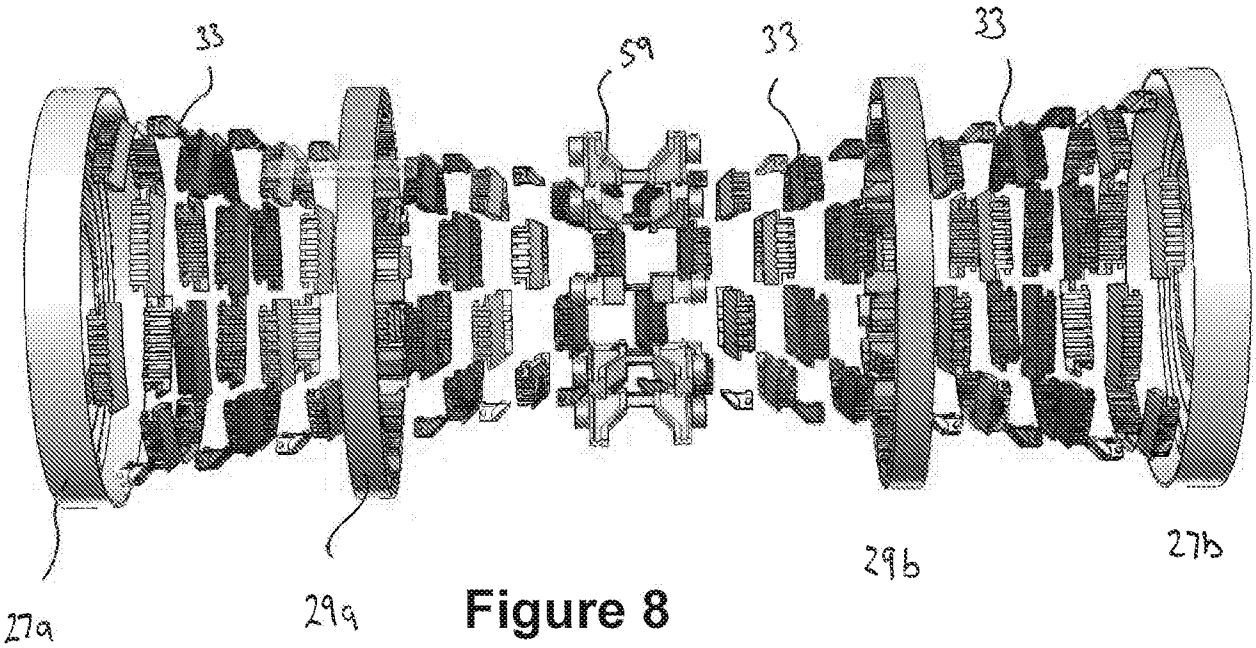
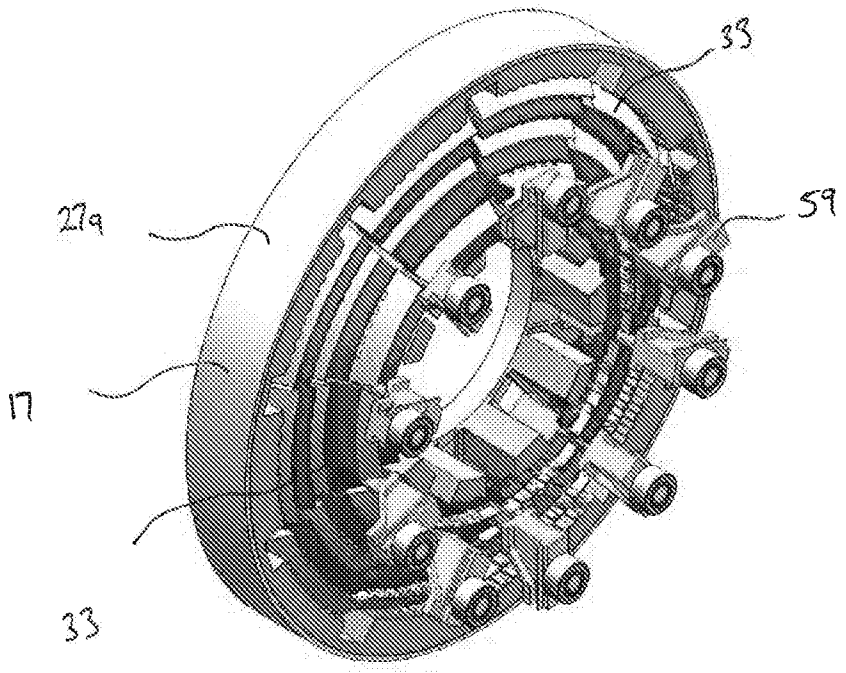


Figure 8



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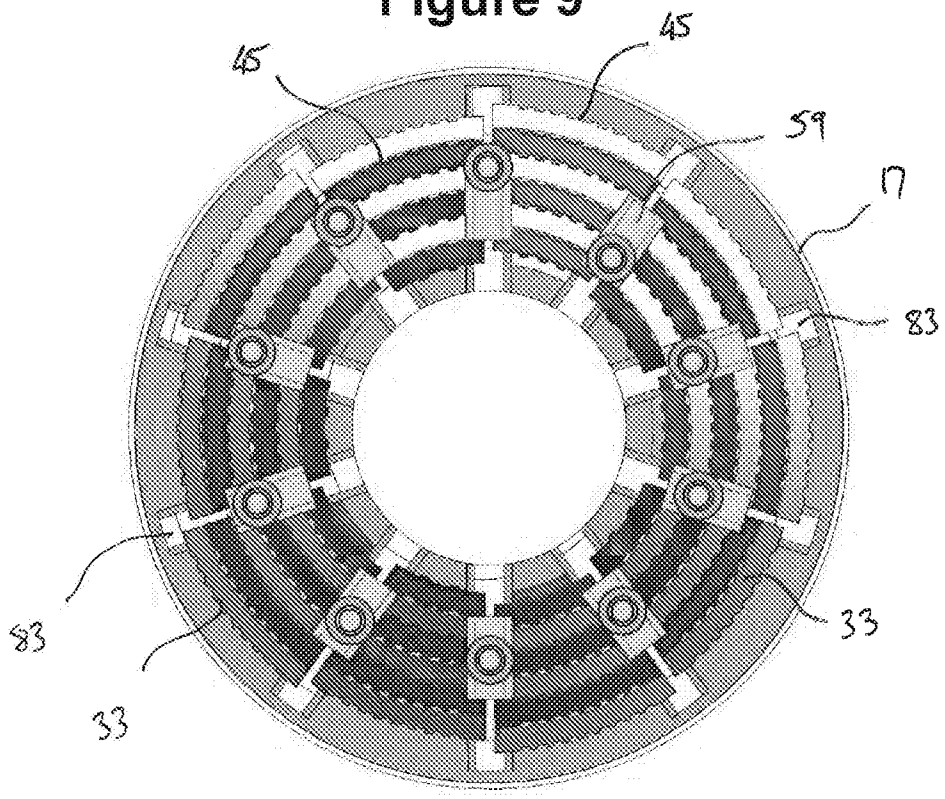


Figure 10

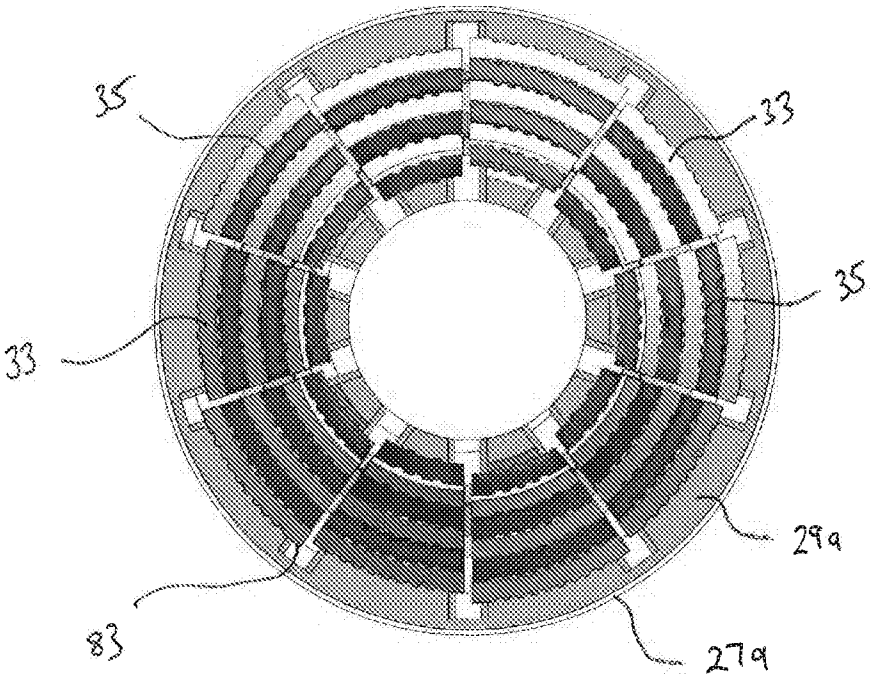
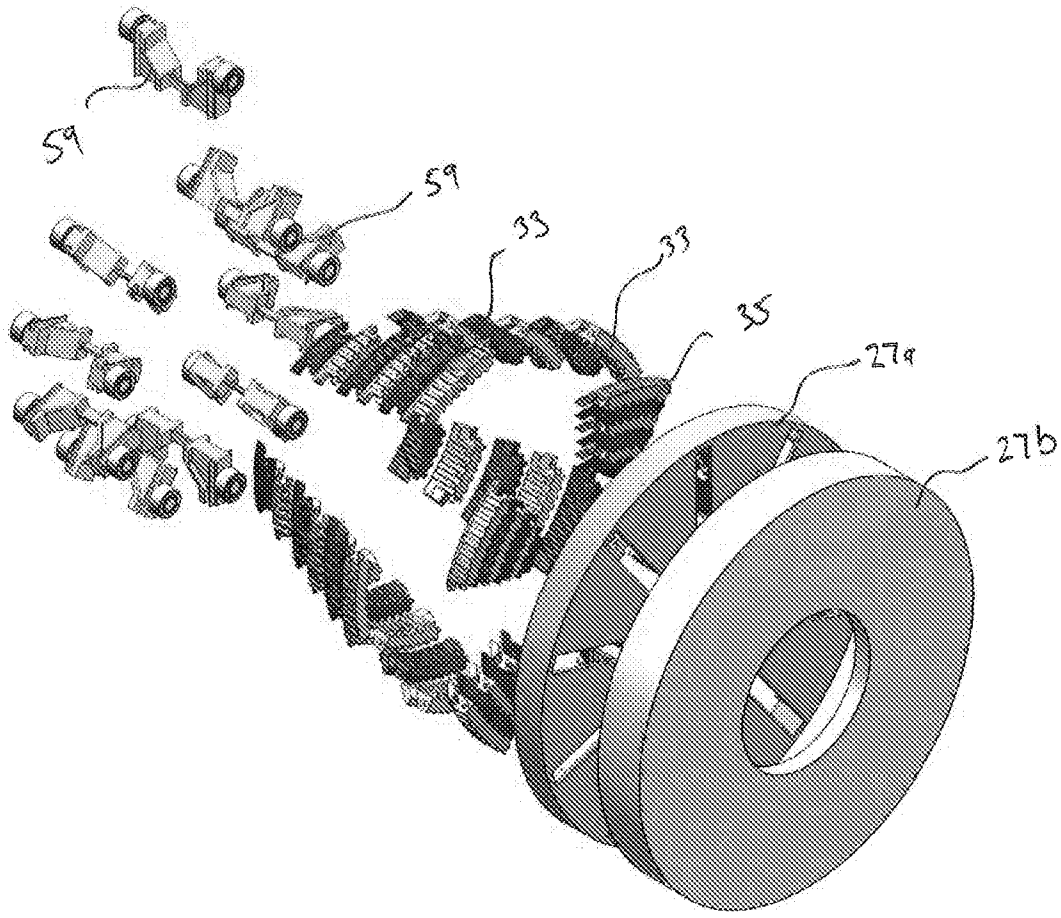


Figure 11



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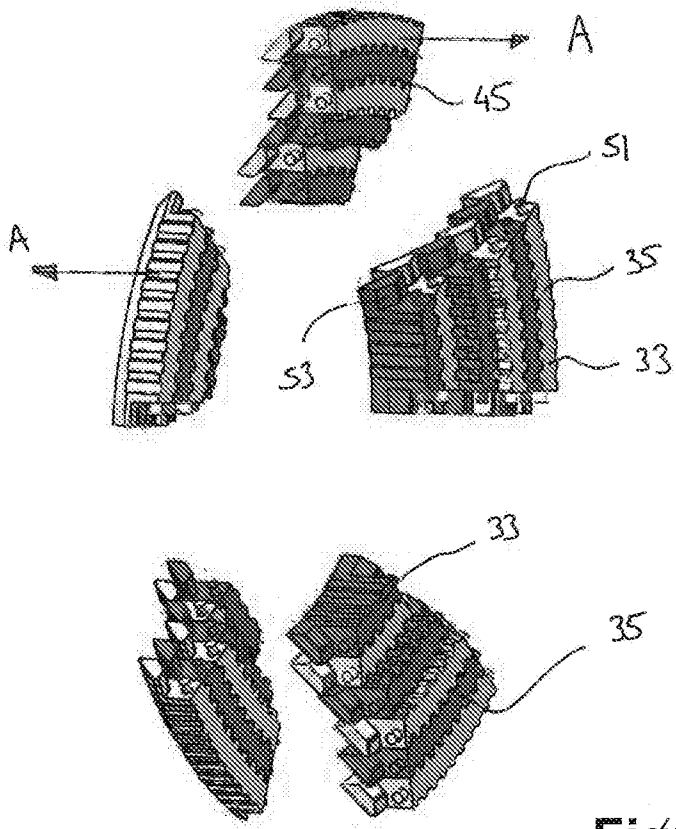


Figure 13

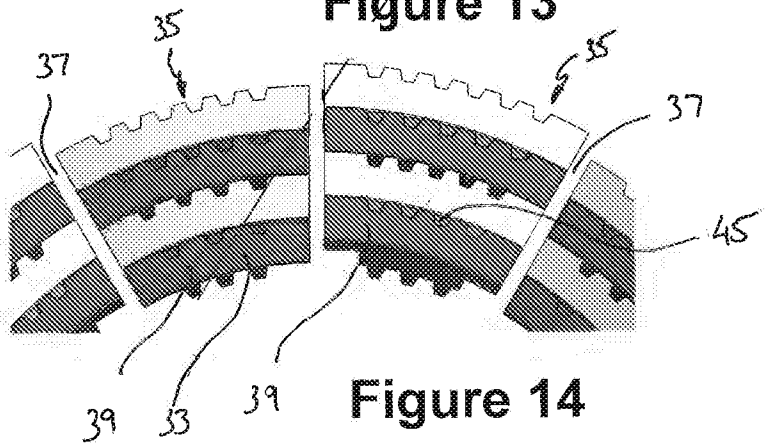


Figure 14

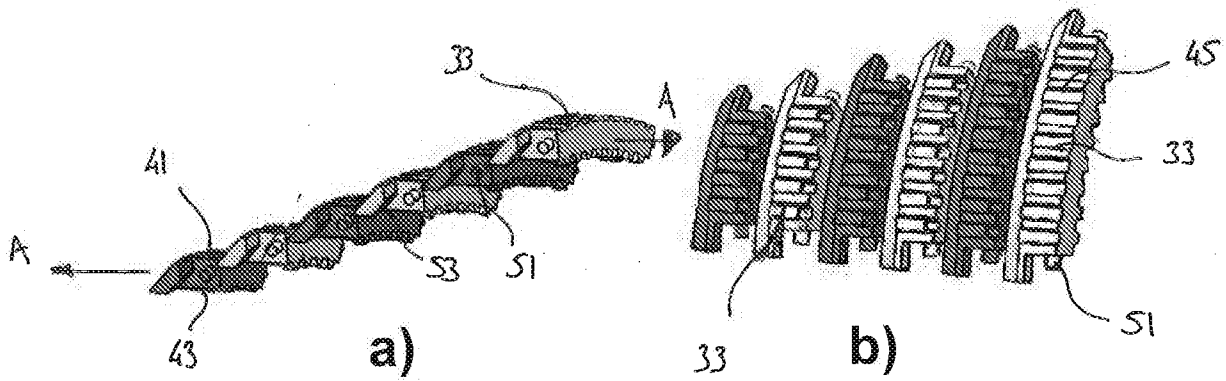


Figure 15

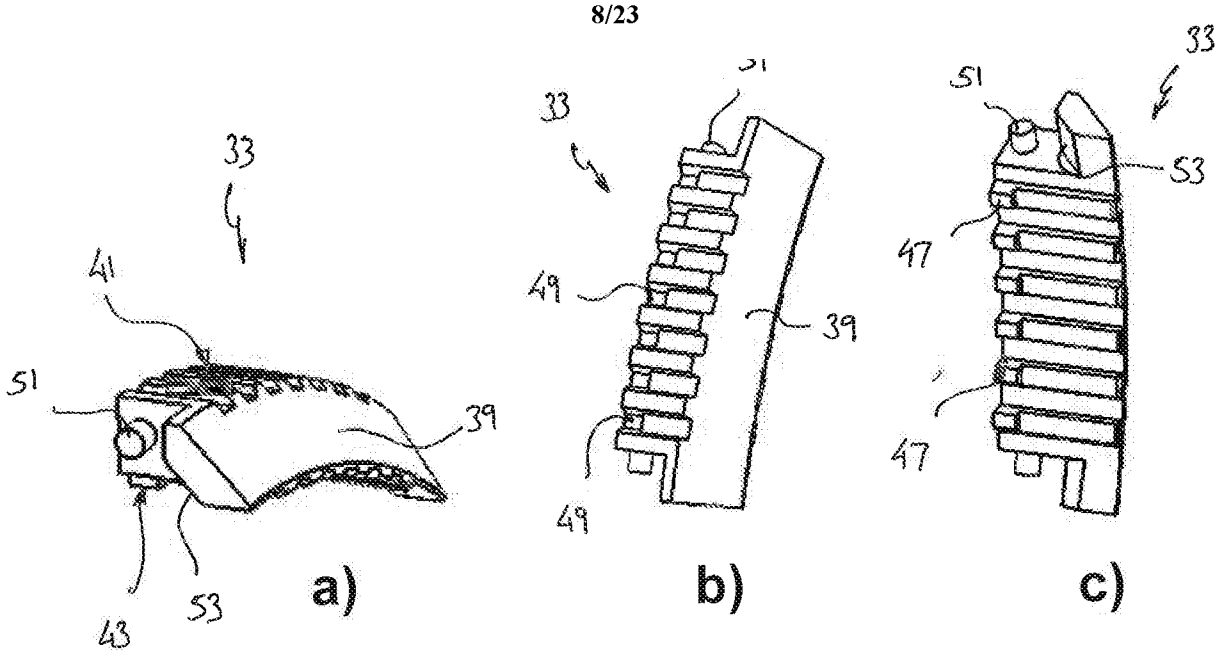
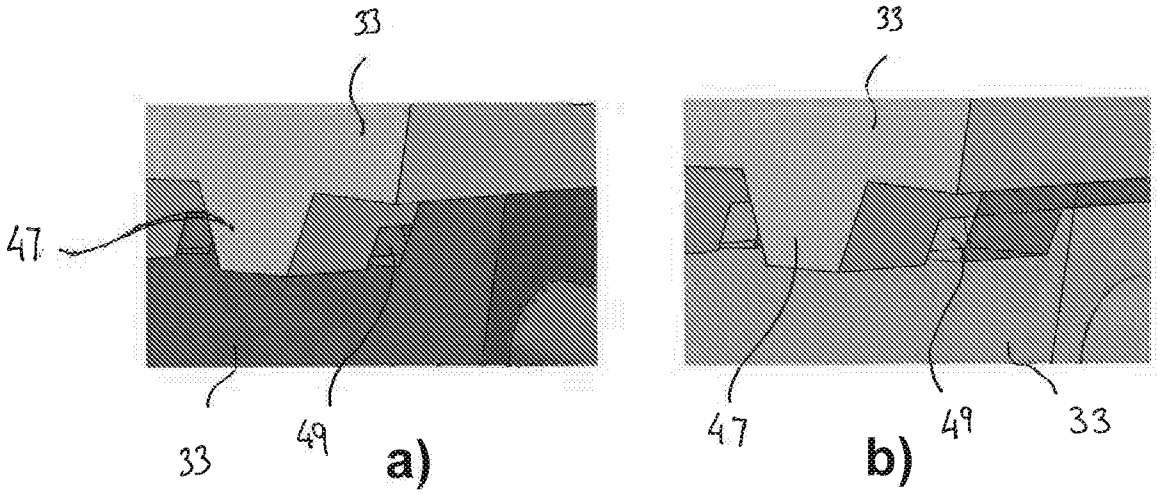


Figure 16



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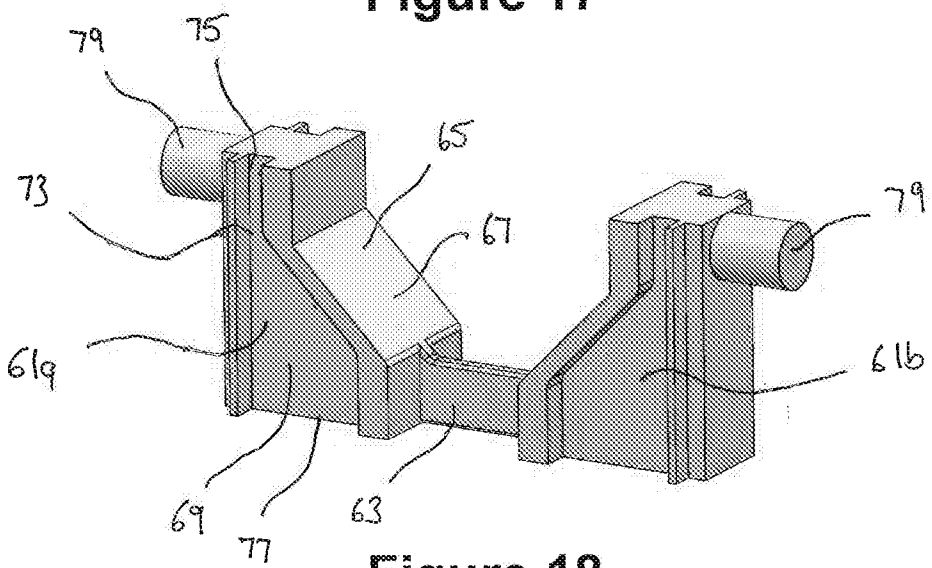
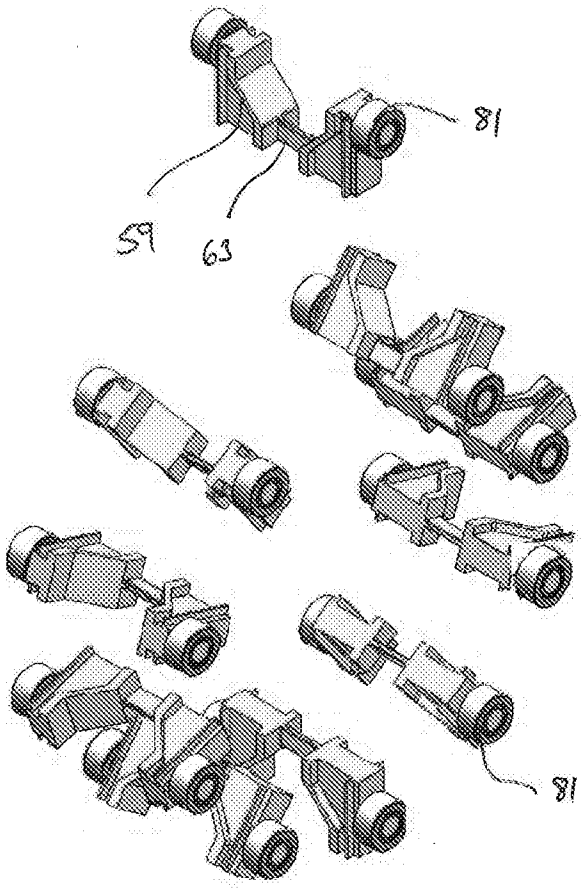


Figure 18



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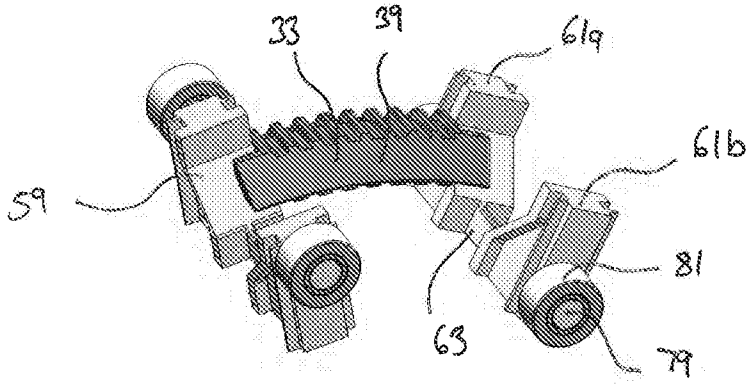

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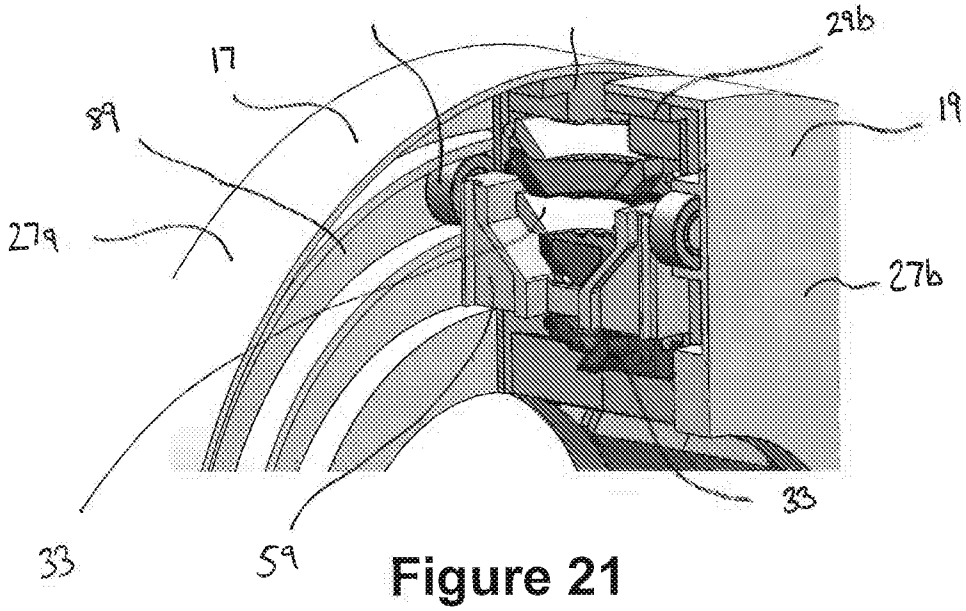
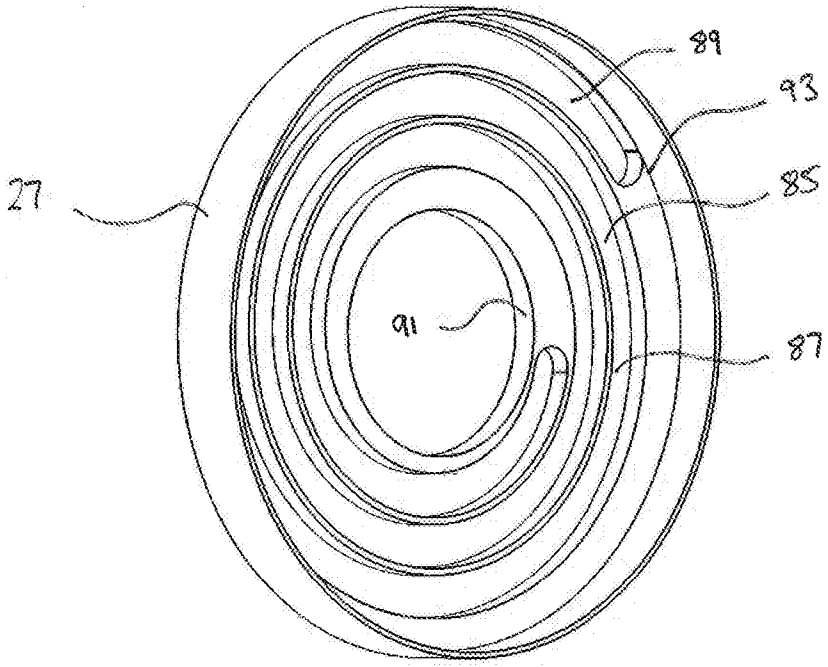


Figure 21



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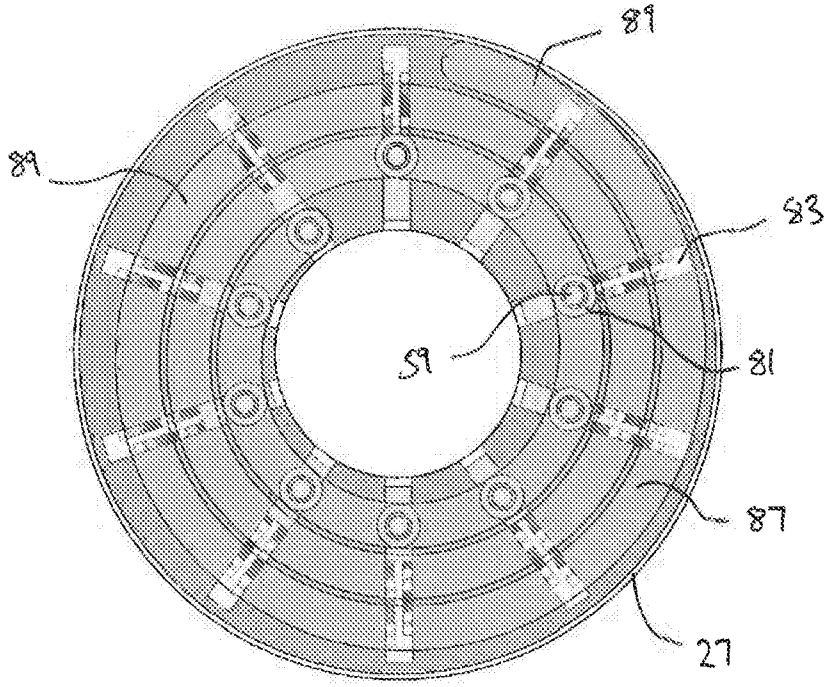
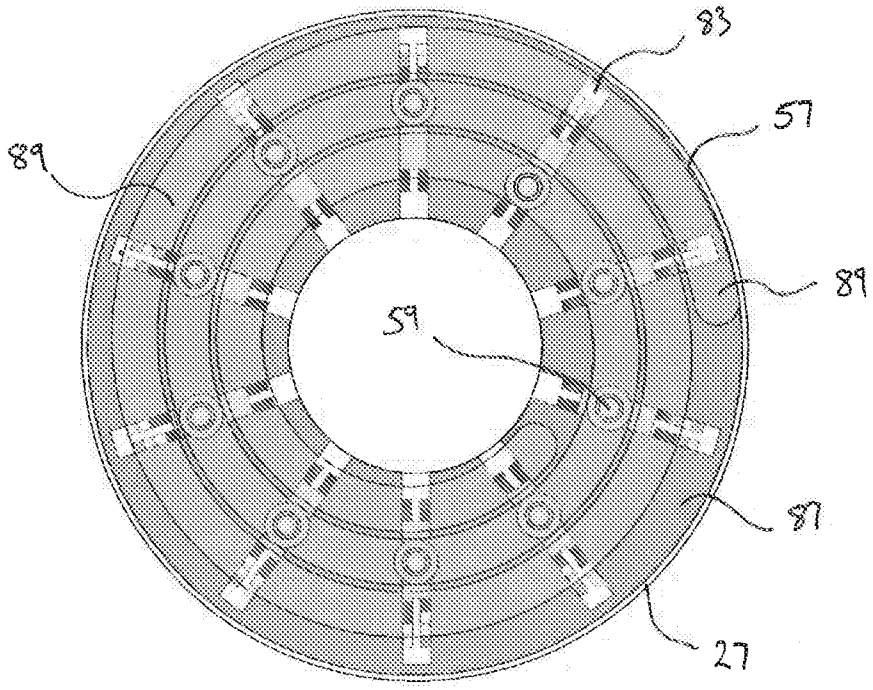


Figure 23



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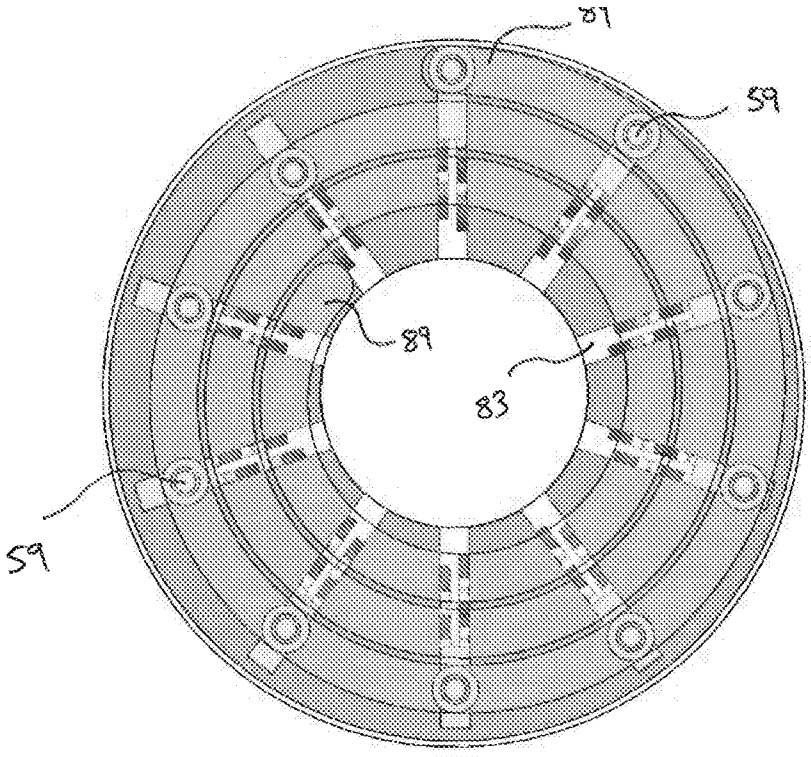

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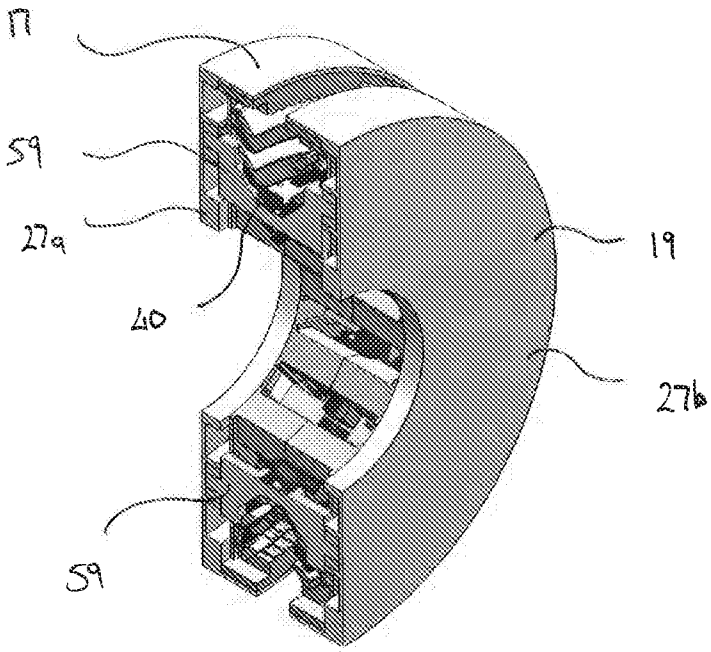

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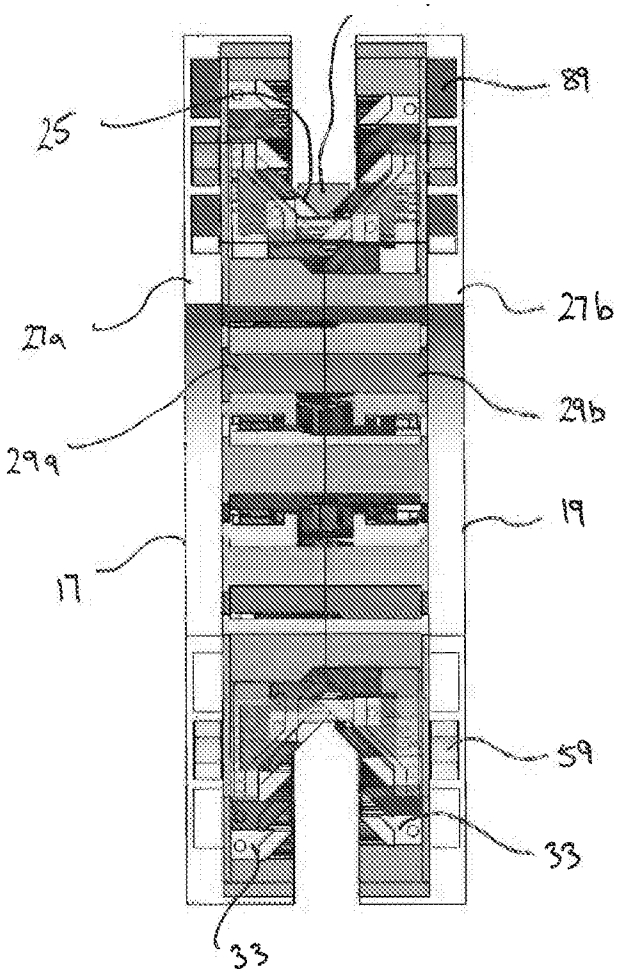

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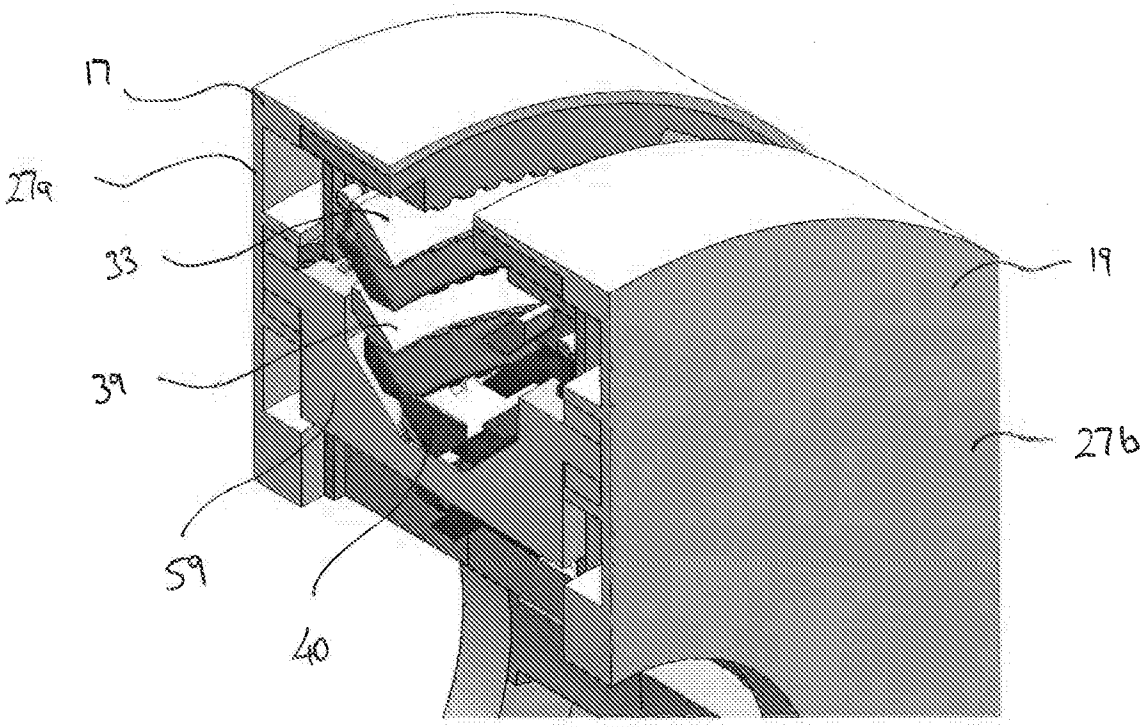

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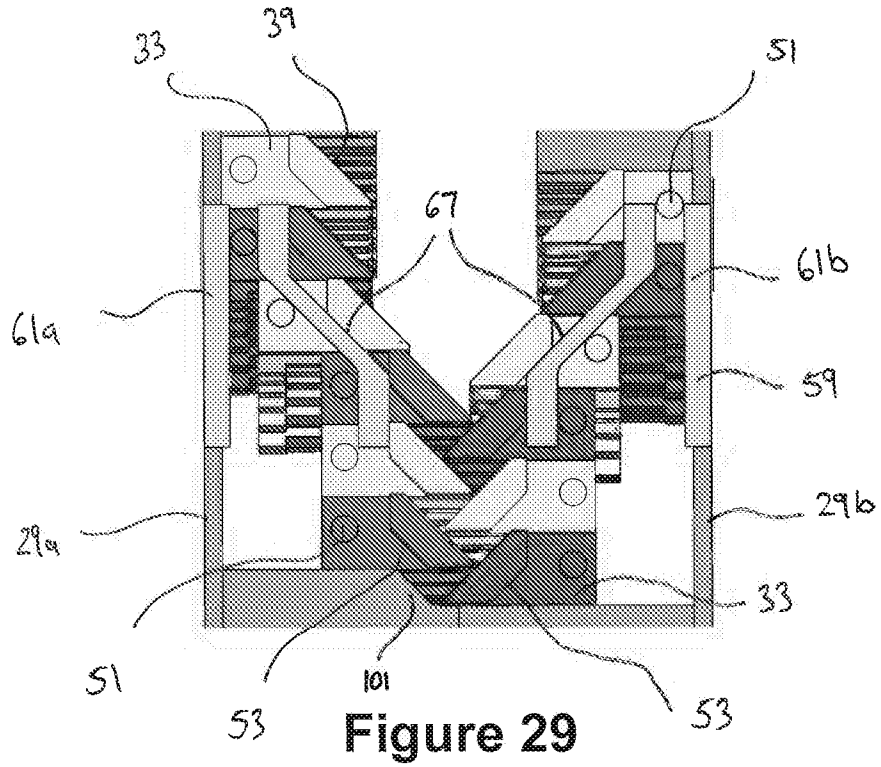

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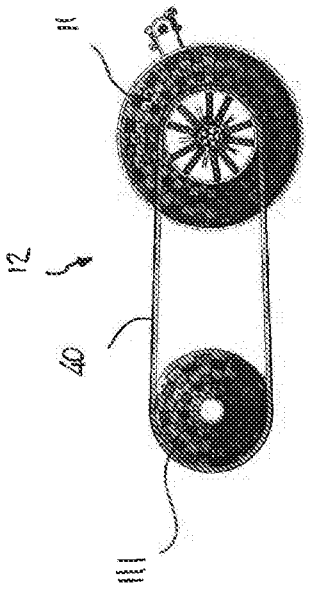
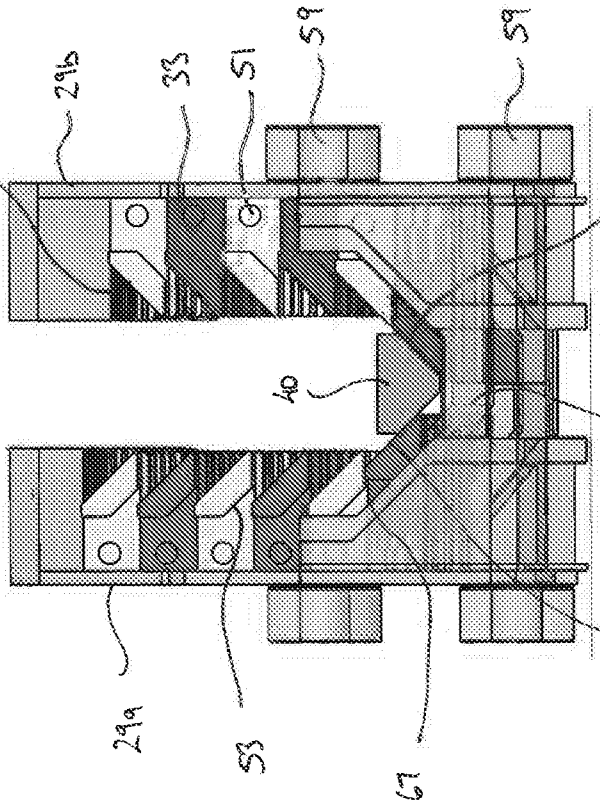


Figure 30



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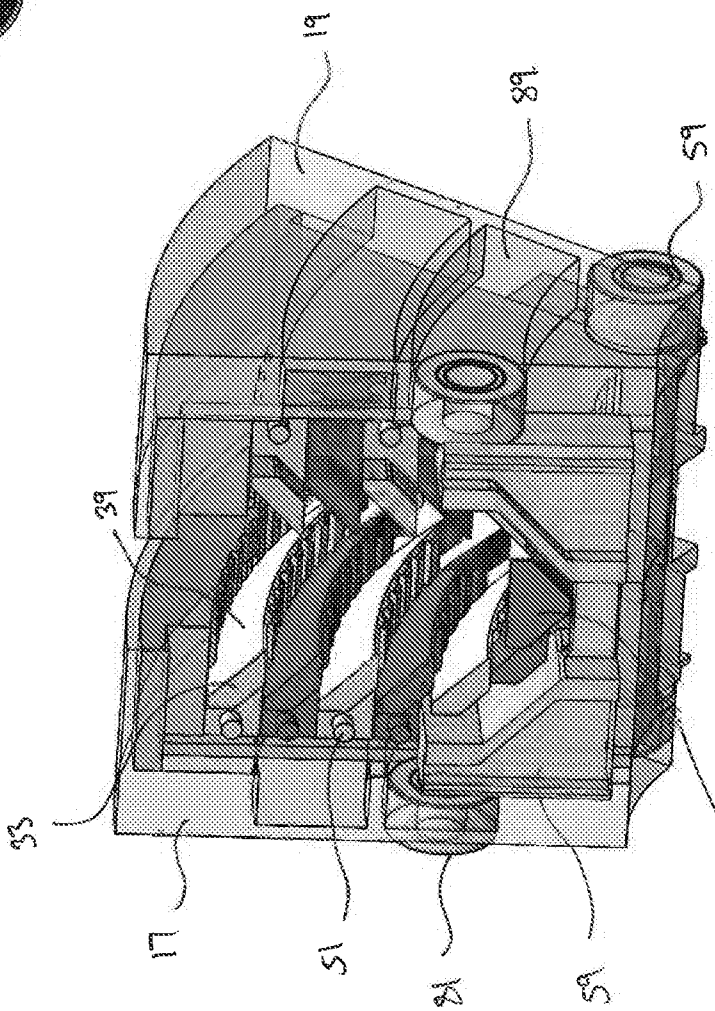

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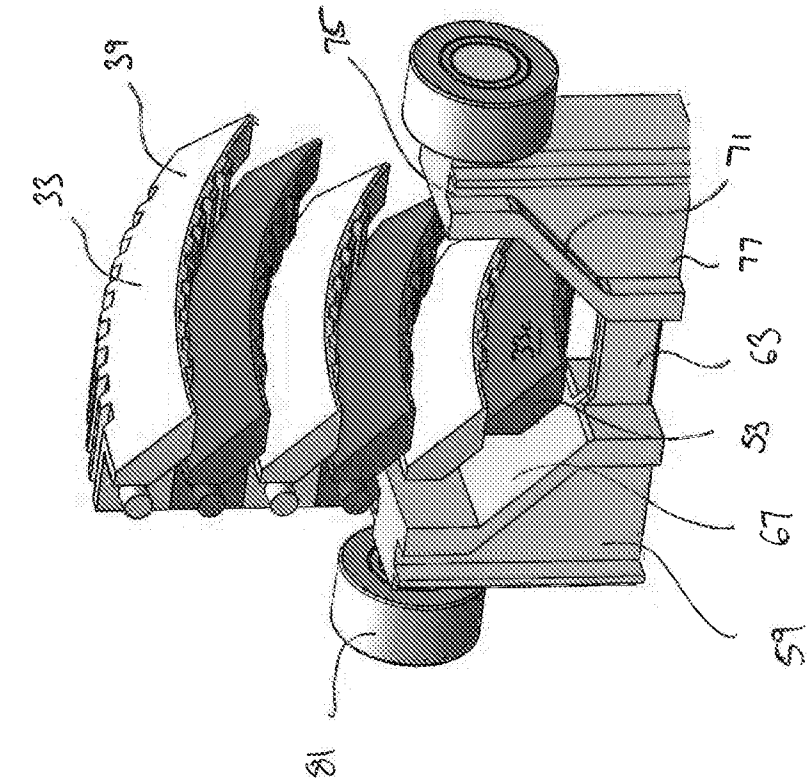

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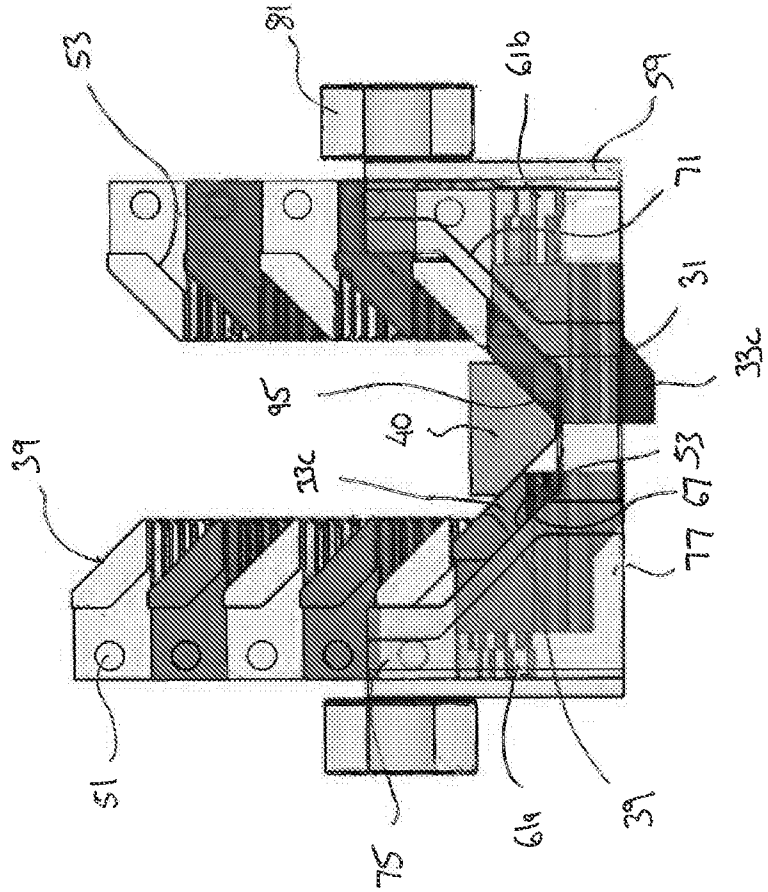


Figure 33

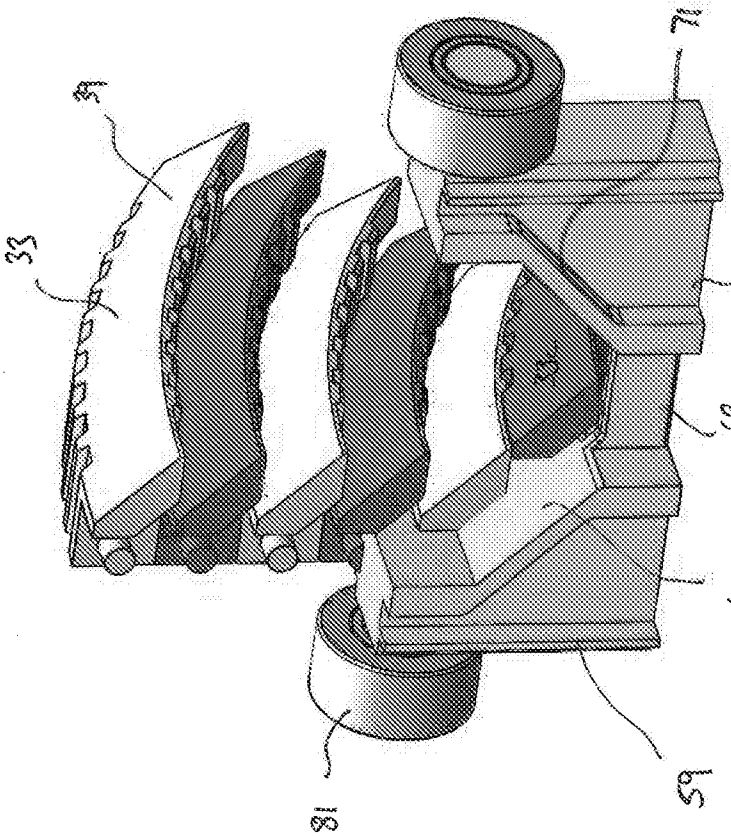


Figure 36

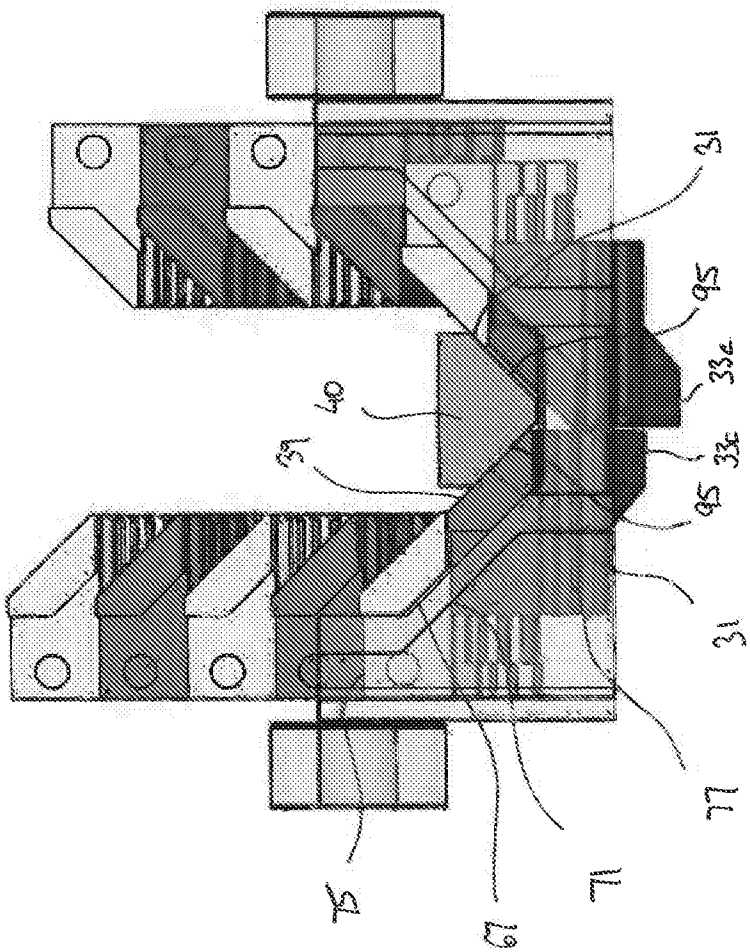


Figure 35

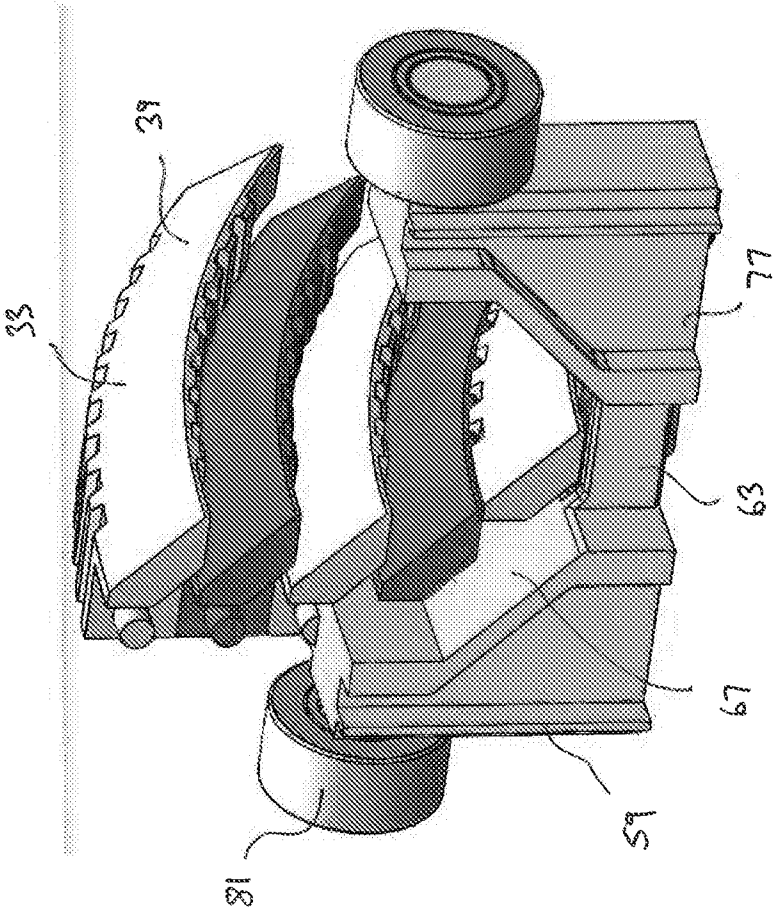


Figure 38

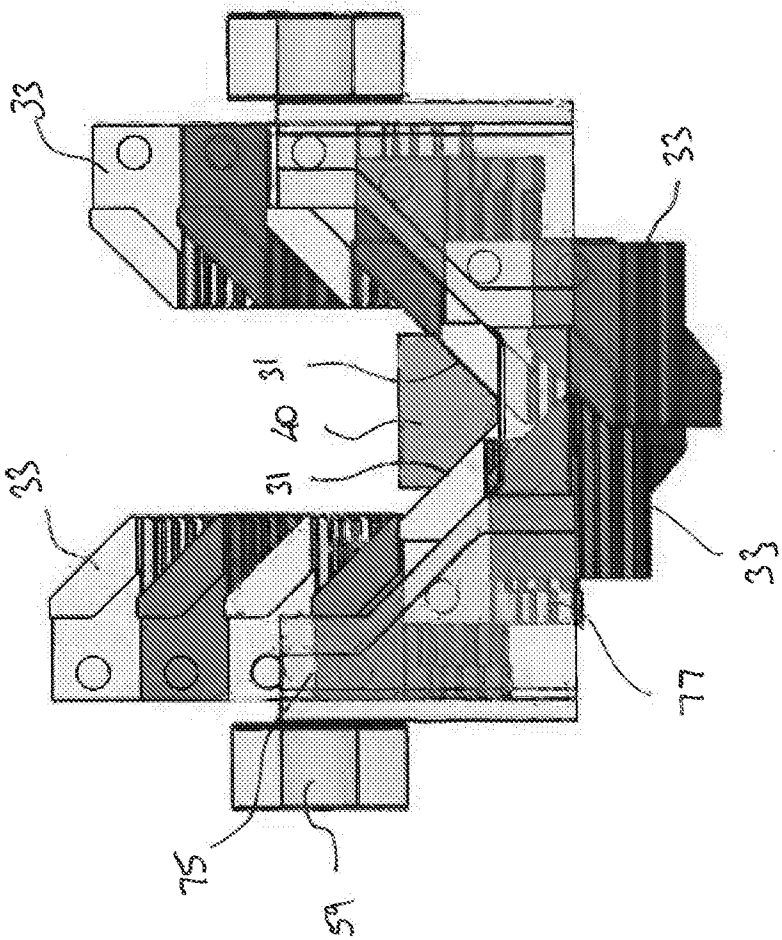
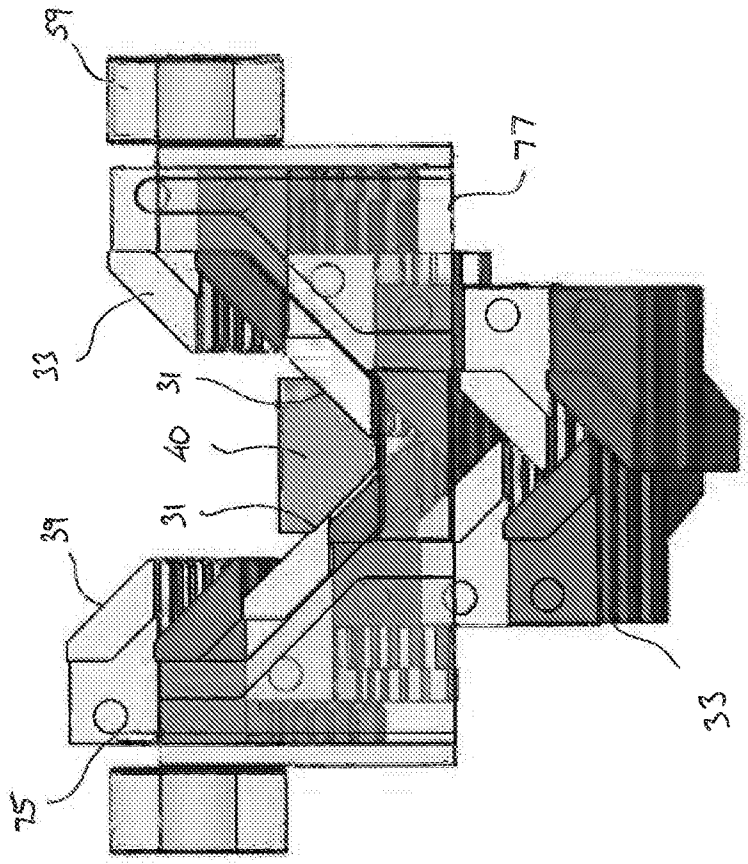


Figure 37



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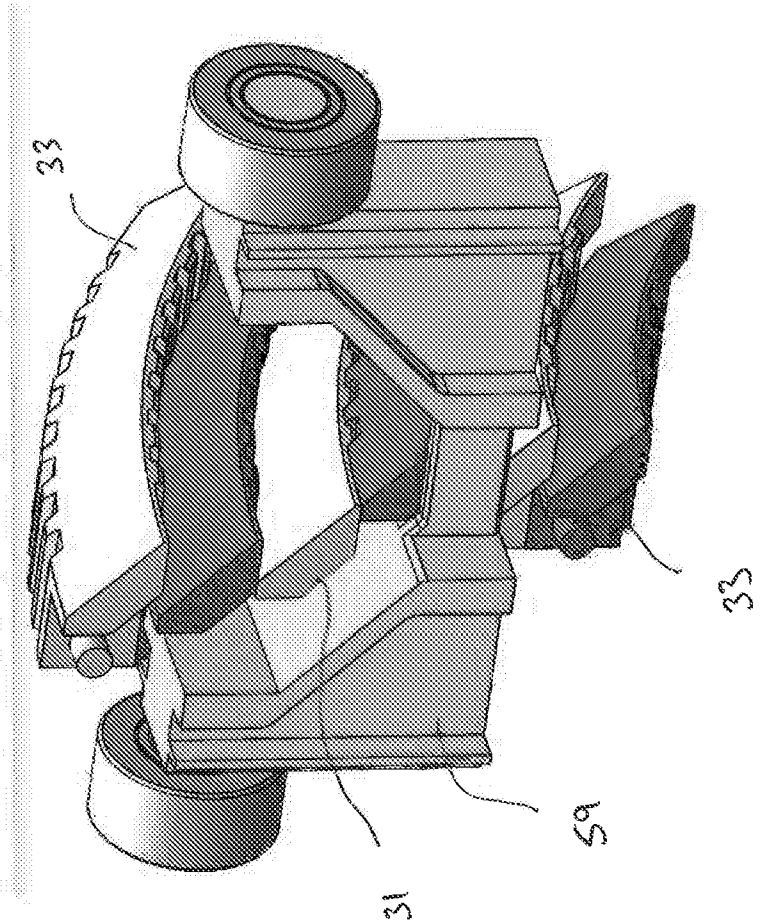
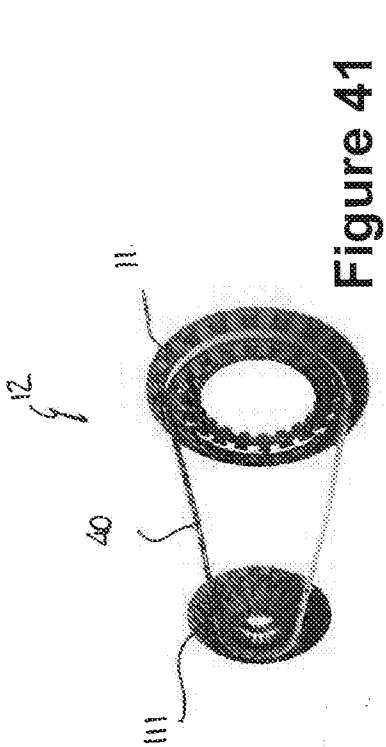


Figure 39



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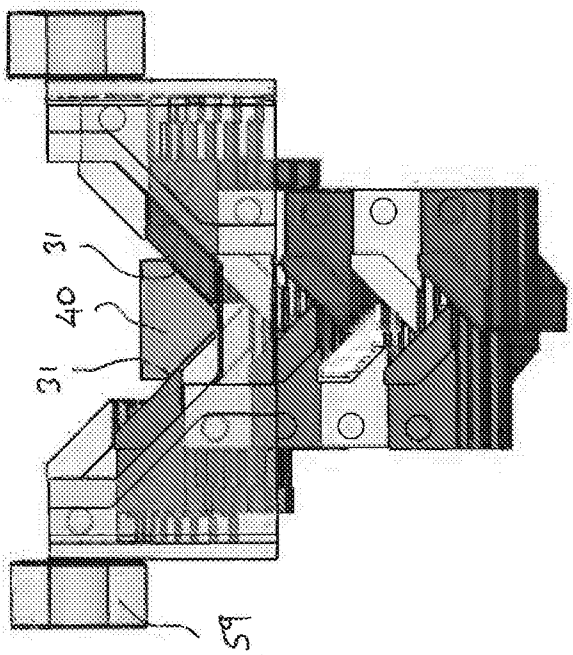


Figure 43

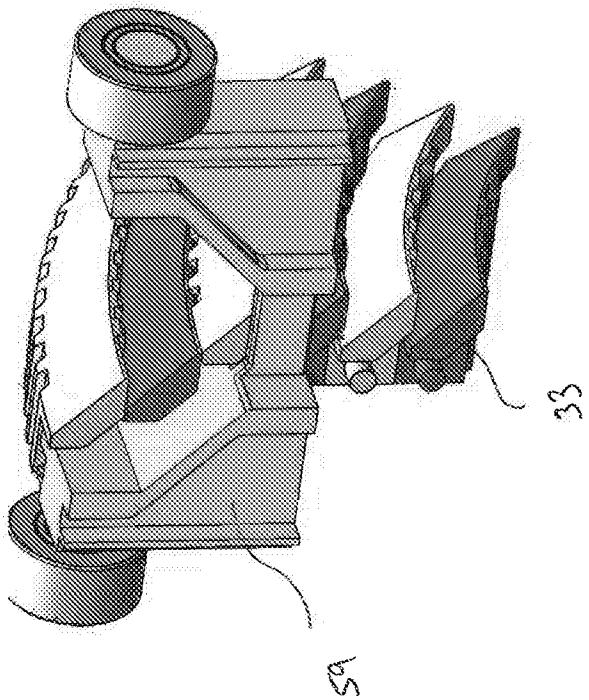
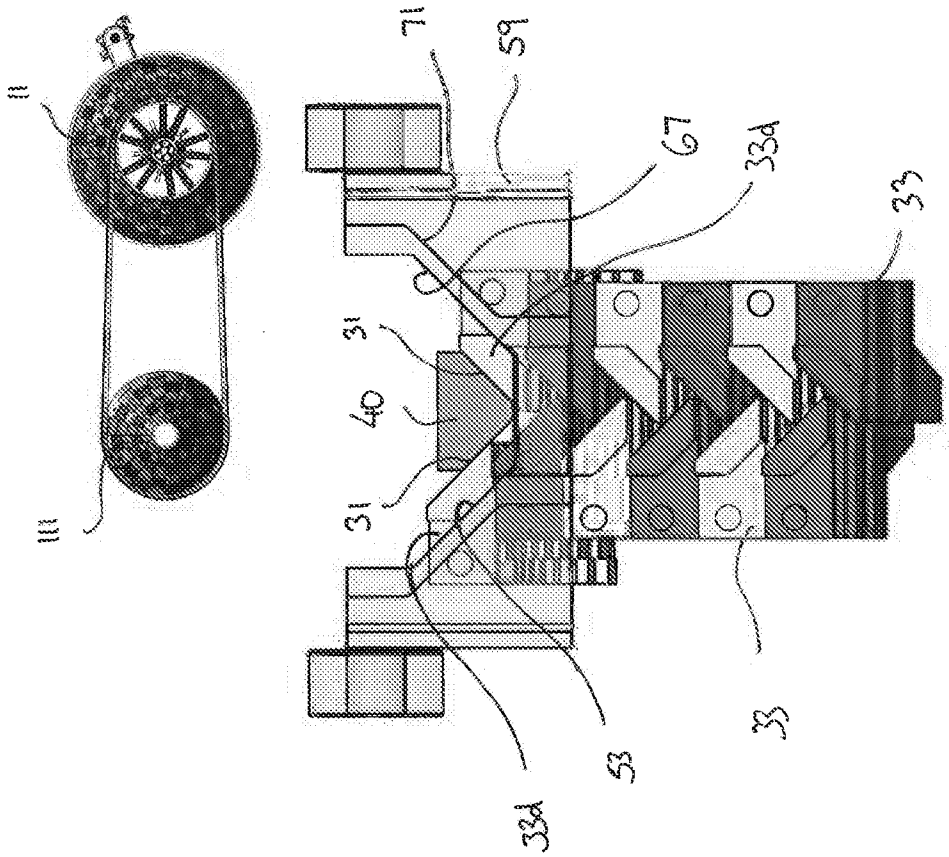


Figure 42

Figure 44



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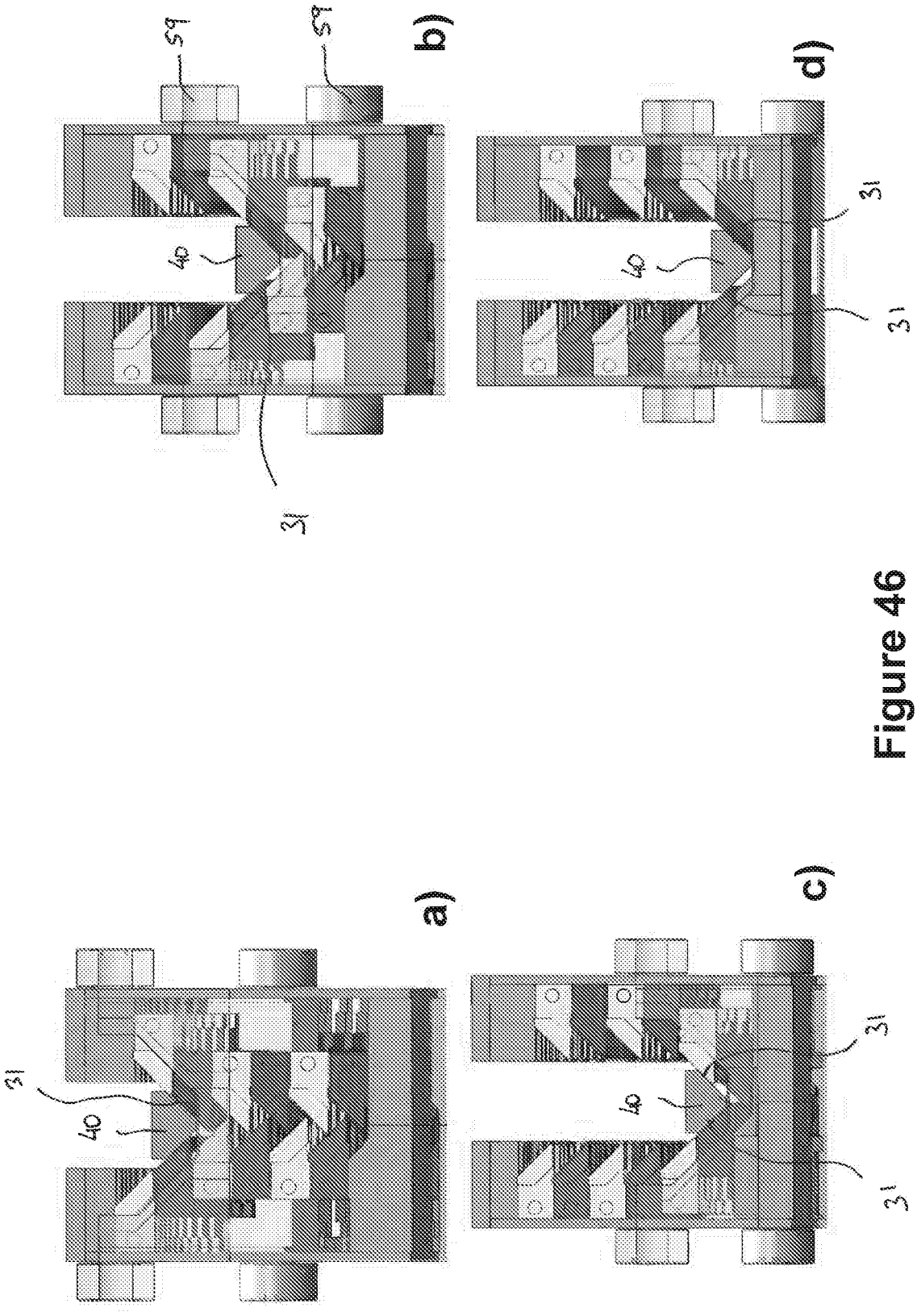

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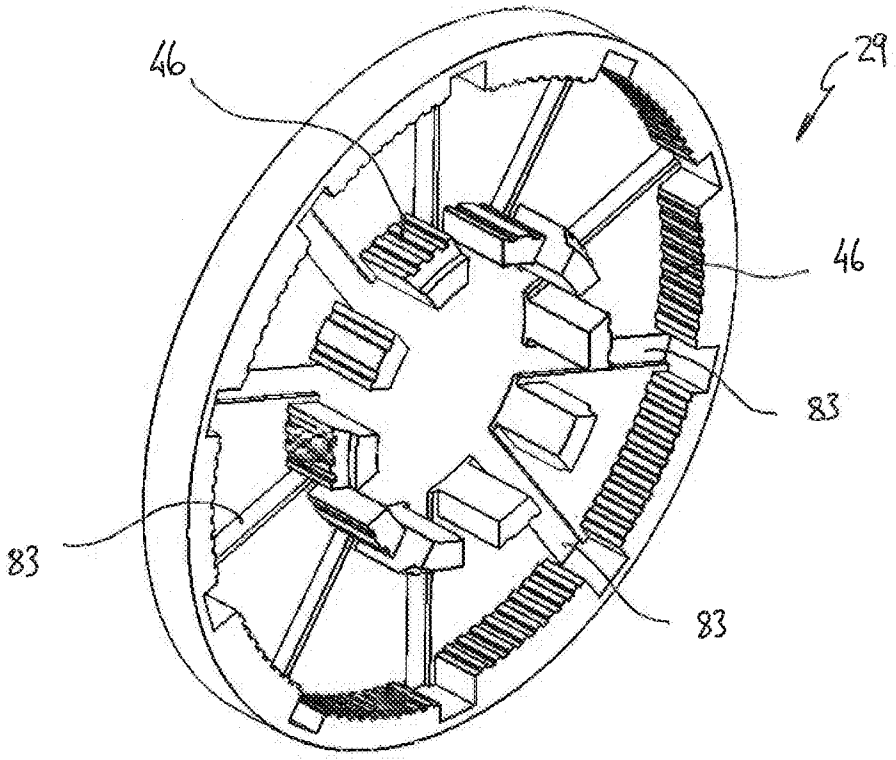

Figure 47

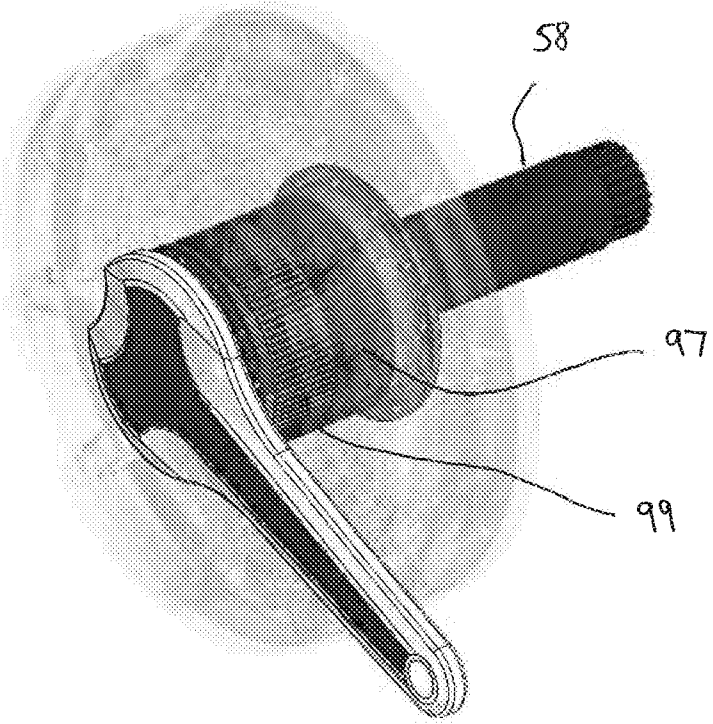

Figure 48

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2018/050724

A. CLASSIFICATION OF SUBJECT MATTER

F16H 55/54 (2006.01) F16H 9/10 (2006.01) B62M 9/08 (2006.01) F16H 63/06 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

A) Database: PATENW; IPC/CPC: F16H55/54, F16H55/56, F16H9/10, F16H9/12, F16H55/46, B62M9/08, B62M25/08, F16H63/06, F16H2007/0868, F16H2007/0874, F16H2007/0872, F16H61/66; Keywords: PLURALITY OF SUPPORT SURFACES, FIRST AND SECOND SIDE ASSEMBLY, PAIR OF SIDE ASSEMBLY, FIXED WIDTH PULLEY, SPIRAL GUIDE, SUPPORT SURFACE SLIDES SIDEWAY, VARIABLE DIAMETER - and other like terms;
B) Database: Google Patents; Keywords:BICYCLE CVT TRANSMISSION, SPLIT PULLEY TRANSMISSION - and other like terms;
C) Database: Google/Google Images; Keywords: BICYCLE CVT TRANSMISSION, RADIALLY ADJUSTABLE PULLEY TRANSMISSION - and other like terms;
Applicant/Inventor name searched in Espacenet, Auspat, and internal databases provided by IP Australia

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 September 2018	11 September 2018

Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Erond Perez AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. +61262832334

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2018/050724

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:

because they relate to subject matter not required to be searched by this Authority, namely:

the subject matter listed in Rule 39 on which, under Article 17(2)(a)(i), an international search is not required to be carried out, including

2. ☐ Claims Nos.:

because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos:

because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/AU2018/050724**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/111463 A1 (WONG et al.) 24 November 2005 ABSTRACT; FIG 1-4; PARA [0019, 0022, 0025, 0035, 0058]	1, 21-28, 32-40, 45, 48-50, 57-68
X	US 2013/0274042 A1 (CHO) 17 October 2013 ABSTRACT; FIG 1-13, 17; PARA [0039-0042]	1-20, 29-32, 59, 68-69, 72-73
X	WO 2017/070736 A1 (TREADLIE ENGINEERING PTY LTD) 04 May 2017 ABSTRACT; FIG 2-11, 18-36; PARA [0029, 0030, 0032, 0039, 0040, 0042, 0069, 0078, 0099, 0105, 0117-0127]	1, 32-33, 40-68, 70-71, 74
X	US 5468191 A (MONAHAN) 21 November 1995 FIG 1-5	59
A	US 601660 A (KIRCHHOFF) 05 April 1898	
A	US 2702484 A (ARATA) 22 February 1955	

INTERNATIONAL SEARCH REPORT	International application No. PCT/AU2018/050724

Supplemental Box

Continuation of: **Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-31 are directed to a transmission system. The feature of "the width of the first pulley remains constant as the support surface moves between the first diameter and the second diameter, and vice versa" is specific to this group of claims.

- Claim 32 is directed to a transmission system. The feature of "independently mounted support surface units" is specific to this claim.

- Claims 33-55 are directed to a transmission system. The feature of "when a first portion of the support surface of each side assembly is in the first position, and a second portion of the support surface is in the second position the cable is supported on the first pulley which is at a third diameter, the third diameter being a diameter between the first diameter and the second diameter" is specific to this group of claims.

- Claim 56 is directed to a transmission system. The feature of "each ring being independently movable by at least one actuator apparatus" is specific to this claim.

- Claims 57-58 and 60-74 are directed to a transmission system. The feature of "the pair of support surfaces being moveable in a lateral direction between a spaced condition, wherein the pair of support surfaces do not engage the cable, and a meshed condition, wherein the pair of support surfaces support the cable at a second diameter of the pulley, the second diameter being larger than the first diameter" are specific to this group of claims.

- Claim 59 is directed to variable diameter pulley. The feature of "the support surface is positionable to present any diameter between the first diameter and the second diameter" is specific to this claim.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is *a pulley comprising a support surface for supporting a cable wherein the support surface is movable to support the cable at a first diameter and a second diameter*. However this feature does not make a contribution over the prior art because it is disclosed in:

D1: WO 2005/111463 A1 (WONG et al.) 24 November 2005

D2: US 2013/0274042 A1 (CHO) 17 October 2013

D3: WO 2017/070736 A1 (TREADLIE ENGINEERING PTY LTD) 04 May 2017

D4: US 5468191 A (MONAHAN) 21 November 1995

Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a posteriori*.

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/AU2018/050724**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

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Publication Number	**Publication Date**	**Publication Number**	**Publication Date**

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.