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ACTUATION MECHANISM

Abstract

A clutch assembly, such as a controllable clutch, having an actuator for controlling coupling members for engagement and disengagement of components. The actuator includes a cam member with a first cam surface and a second cam surface. The first cam surface is spaced from the second cam surface. A first cam follower follows the first cam surface and a second cam follower follows the second cam surface. A first link extends between the first cam follower and a first coupling member, and a second link extends between the second cam follower and a second coupling member.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation-in-part of U.S. patent application Ser. No. 18/566,855 filed on Dec. 4, 2023, which is a National Stage of International Application No. PCT/US 2022/046073, filed Oct. 7, 2022, and claims the benefit of U.S. Provisional Application No. 63/253,401, filed Oct. 7, 2021. The disclosure of the above applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION
1. Field of the Invention
[0002] The present invention generally relates to actuators for controlling engagement and disengagement of power components.
2. Description of Related Art
[0003] A one-way clutch ("OWC") includes a first coupling member, a second coupling member, and at least one locking element between opposing surfaces of the coupling members. The locking element moves between a deployed or engaged position, in which the locking element extends from the first coupling member and engages the second coupling member, and a non-deployed or disengaged position in which the locking element does not extend from the first coupling member and does not engage the second coupling member. In the deployed position, the locking element engages the second coupling member wherein the OWC locks in one direction of rotation but has free rotation in the opposite direction.
[0004] A selectable OWC ("SOWC") produces a mechanical connection between rotating or stationary components in one or both directions and can overrun in one or both directions. A selectable OWC, also known as a two-way clutch, adds a second set of locking elements in combination with a selector plate. The second set of locking elements, plus the selector plate, adds multiple functions to the OWC. The selector plate is adjustable between different positions to implement the different operating modes.
[0005] A dynamically controllable clutch or dynamic selectable clutch ("DCC") fits in positions where typically dog clutches, synchronizers, and wet friction packs would be located.
[0006] FIGS. **1-5** show a DCC **12** according to the prior art. DCC **12** is a component of a system (not shown), such as an automotive transmission, further having an input power component (e.g., a drive shaft) and an output power component (e.g., a driven shaft).
[0007] The dynamically controllable clutch (DCC) **12** has a radially inner rotating race, i.e., a first coupling member in the form of a pocket plate **13** (FIGS. **4** and **5**), and a radially outer rotating race, i.e., a second coupling member in the form of a notch plate **16**. The pocket plate **13** is fixedly connected to a first power component of the system, and the notch plate **16** is fixedly connected to a second power component of the system. Consequently, the first and second power components are connected when pocket and notch plates **13** and **16** are connected.
[0008] The pocket plate **13** contains first and second sets of radial locking elements **26** for clockwise ("CW") and counterclockwise ("CCW") engagement, respectively. During engagement, at least one of the sets of locking elements **26** simultaneously contacts the pocket and notch engagement faces of the pocket and notch plates **13**, **16**, connecting the pocket and notch plates **13**, **16** together. The pocket and notch plates **13**, **16** connect the first and second power components. Consequently, in each locked direction of rotation, the DCC **12** transmits torque between the power components, which are connected via the connected pocket and notch plates **13** and **16**.
[0009] DCC **12** is actuated by an actuation system in the form of a linear motor or linear actuator **14**. The linear actuator **14** includes a stator **22** and a translator **20**. Stator **22** is fixed in position, for

example, to a transmission case (not shown) via mounts **47**. The stator **22** includes a pair of copper wire induction coils **44**, **46**. Steel plates **48**, **50**, and **52** provide a housing for the stator coils **44**, **46**. The stator coils **44**, **46** are wound in series with reversed polarity relative to one another, anti-series.

[0010] The translator **20** linearly moves between lateral, axial positions. The translator **20** is fixedly connected to and rotates with the pocket plate **13**. The translator **20** includes an annular ring of segmented permanent magnets **21**, steel plates **23**, **25**, and rigid plungers **30**. The plungers **30** operate the locking elements **26**. The plungers **30** extend through holes formed through a carriage **51** of the translator **20** and are biased by springs **34**. The plungers **30** are threaded at their ends and secured within their holes by internally threaded nuts **35**. The conical ends of plungers **30** extend through the apertures of a ring **55**.

[0011] FIGS. **2-5** show the linear actuator **14** controlling the locking elements **26**. Depending on actuation direction, the plungers **30** within the translator **20** directly contact the locking elements **26** and cause them to pitch up or down. The linear actuator **14** has an "off" position, shown in FIGS. **2** and **4**, and an "on" position, shown in FIGS. **3** and **5**. The linear actuator **14** switches between the "off" and "on" positions by causing the translator **20** to laterally move between, in this case, a right-most position, shown in FIGS. **2** and **4**, and a left-most position shown in FIGS. **3** and **5**.

[0012] When the translator **20** moves from "off" to "on," each plunger **30** contacts the under face or surface of its locking element **26** so the locking element can engage the notch plate **16**. The DCC **12** transmits torque in each locked direction of rotation when the locking elements **26** are engaged with notch plate **16**. A return spring **28** under each locking element **26** is compressed during the engaged state. When commanded "off," the translator **20** moves back toward the "off" position, and the plungers **30** lose contact with the locking elements **26**. Compressed return springs **28** create a force causing the locking elements **26** to pitch downward or disengage. Once a torque reversal occurs, the locking elements **26** can disengage, and the DCC **12** can freewheel.

[0013] To change the state from "off" to "on," an electrical current energizes the stator coil **46** nearest to the translator **20**. The energized stator coil **46** produces a magnetic field that repels the steady state field generated by the permanent magnets **21**, while the far stator coil **44** produces an attractive magnetic field. The combination of repelling and attracting forces caused by the stator coils **44** and **46** causes the translator **20** to move.

[0014] Once the translator **20** passes over the center stator steel plate **50**, the permanent magnets **21** attempt to fully align the left-most stator steel plate **48**. A mechanical stop **53**, shown in FIGS. **4** and **5**, prevents complete alignment, which results in a biasing force that holds the translator **20** in the "on" position. The translator **20** is magnetically latched in the "on" position.

[0015] To disengage the DCC **12**, electrical current is applied to the stator coil **44** nearest to the translator **20**, formerly the far stator coil **46**, and the linear actuator **14** moves from the "on" stop **53** to a ring which functions as an "off" stop **42** in a similar manner described above. The "off" mechanical stop **42** prevents complete alignment of the permanent magnet **21** and the right-most stator steel plate **52**, remaining magnetically latched in the "off" position.

SUMMARY OF THE INVENTION

[0016] An actuation mechanism having an actuator for controlling the engagement and disengagement of power components.

[0017] The actuator includes a cam member having a first cam surface and a second cam surface, the first cam surface spaced from the second cam surface. A first cam follower, the first cam follower following the first cam surface, and a second cam follower, the second cam follower following the second cam surface. A first link extends between the first cam follower and a first coupling member, and a second link extends between the second cam follower and a second coupling member.

[0018] Further areas of applicability of the present invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while indicating the preferred embodiment of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The present invention will become more fully understood from the detailed description and the accompanying drawings.

[0020] FIG. **1** is an exploded view of a dynamically controllable clutch (“DCC”) in accordance with the prior art.

[0021] FIG. **2** is a perspective view, partially broken away and in cross-section, of the prior art DCC with a linear actuator of the DCC being in an “off” position whereby the DCC is in a freewheel mode.

[0022] FIG. **3** is a perspective view, partially broken away and in cross-section, of the prior art DCC with the linear actuator being in an “on” position whereby the DCC is in a lock mode.

[0023] FIG. **4** is a side view, partially broken away and in cross-section, of the prior art DCC with a translator of the linear actuator magnetically latched in the “off” position, wherein FIGS. **2** and **4** pertain to the same condition of the DCC.

[0024] FIG. **5** is a side view, partially broken away and in cross-section, of the prior art DCC with the translator of the linear actuator magnetically latched in the “on” position, wherein FIGS. **3** and **5** pertain to the same condition of the DCC.

[0025] FIG. **6** is an exploded view, from the right side, of a system having an actuation mechanism according to one embodiment of the present invention.

[0026] FIG. **7** is a partial, exploded view, from the left side, of the system of FIG. **6**.

[0027] FIG. **8** is a partial, cross-sectional view of the system of FIG. **6**.

[0028] FIG. **9** is a partial, cross-sectional view of the system of FIG. **6**.

[0029] FIG. **10** is a perspective view of one component of the actuation mechanism of FIG. **6**.

[0030] FIG. **11** is a perspective view of another component of the actuation mechanism of FIG. **6**.

[0031] FIG. **12** is a perspective view of the components of FIGS. **10** and **11** in an initial position.

[0032] FIG. **13** is a perspective view of the components of FIGS. **10** and **11** in an extended position.

[0033] FIG. **14** is an exploded view, from the right side, of a system having an actuation mechanism according to another embodiment of the present invention.

[0034] FIG. **15** is a partial, exploded view, from the left side, of the system of FIG. **14**.

[0035] FIG. **16** is a partial, cross-sectional view of the system of FIG. **14**.

[0036] FIG. **17** is a partial, cross-sectional view of the system of FIG. **14**.

[0037] FIG. **18** is a perspective view of a component of the actuation mechanism of FIG. **14**.

[0038] FIG. **19** is a perspective view of another component of the actuation mechanism of FIG. **14**.

[0039] FIG. **20** is a perspective view of yet another component of the actuation mechanism of FIG. **14**

[0040] FIG. **21** is a partial, perspective view of part of the actuation mechanism of FIG. **14** in a first mode.

[0041] FIG. **22** is a cross-sectional view of the actuation mechanism of FIG. **21**.

[0042] FIG. **23** is a partial, perspective view of part of the actuation mechanism of FIG. **14** in a second mode.

[0043] FIG. **24** is a cross-sectional view of the actuation mechanism of FIG. **23**.

[0044] FIG. **25** is a partial, perspective view of part of the actuation mechanism of FIG. **14** in a third mode.

[0045] FIG. **26** is a cross-sectional view of the actuation mechanism of FIG. **25**.

[0046] FIG. **27** is a partial, perspective view of part of the actuation mechanism of FIG. **14** in a fourth mode.
[0047] FIG. **28** is a cross-sectional view of the actuation mechanism of FIG. **27**.
[0048] FIG. **29** is a top view of part of the actuation mechanism of FIG. **14** with portions removed for clarity.
[0049] FIG. **30** is a perspective view of an alternative embodiment of a component of the actuation mechanism of FIG. **14**.
[0050] FIG. **31** is a perspective view of another example of a component for use with an actuation mechanism.
[0051] FIG. **32** is a cross-sectional view of an actuation mechanism including the component of FIG. **31**.
[0052] FIG. **33** is a cross-sectional view of the actuation mechanism of FIG. **32** in a second mode.
[0053] FIG. **34** is a perspective view of a further example of a component for use with an actuation mechanism.
[0054] FIG. **35** is a cross-sectional view of an actuation mechanism including the component of FIG. **34**.
[0055] FIG. **36** is a schematic cross-sectional view of the actuation mechanism of FIG. **35** with portions removed for clarity.
[0056] FIGS. **37**A and **37**B are schematic views of a cam follower for use in the actuation mechanism of FIG. **35**.
[0057] FIG. **38** is a perspective view of yet another example of a component for use with an actuation mechanism.
[0058] FIG. **39** is a perspective view of a cam follower for use with the component of FIG. **38**.
[0059] FIG. **40** is a cross-sectional view of an actuation mechanism including the component of FIG. **38**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0060] The following description of the preferred embodiment(s) is merely exemplary and is in no way intended to limit the invention, application, or use.
[0061] Examples of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale; some features may be exaggerated or minimized to show details of the components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting but merely as a representative basis for teaching one skilled in the art to variously employ the present invention.
[0062] FIGS. **6-13** show one example of a system **100**, including a clutch assembly **102** with a dynamically controllable clutch (DCC) **166** and a linear actuator **104**. The dynamically controllable clutch (DCC) **166** typically includes a pocket plate **142**, a notch plate **144**, and a locking element **150**, shown in FIG. **8**. The pocket plate **142** connects to the first power component, for example a driveshaft **184**, and the notch plate **144** connects to the second power component, for example a driven shaft **182**. The linear actuator **104** includes a first cam member **106** and a second cam member **108**. The linear actuator may also include a spring plate **146**, having return springs **147** and actuation springs **148**, and a thrust plate or bearing member **164**. The actuation springs **148** of the spring plate **146** act on the locking elements **150**, while the return springs **147** of the spring plate **146** contact the pocket plate **142** and bias the second cam member **108** axially toward the first cam member **106**.
[0063] The clutch assembly **102** includes a clutch assembly housing **156**, a bearing **158**, and snap rings **160**, **162**. The first cam member **106** includes a gear sector **152**. The system **100** also includes a motor housing **168** for a motor **170**. The motor **170** includes a motor shaft **172**, a worm **174**, and an O-ring **176**. The motor **170** is configured to actuate the first cam member **106** and cause the first cam member **106** to rotate about the rotational axis **118** in the directions shown by the arrows **132**,

140.

[0064] The clutch assembly **102** includes biasing springs **178**, **180** that maintain contact between the worm **174** and gear sector **152** of the first cam member **106**. In another example, an electric or hydraulic mechanism may be used to rotate the first cam member **106**.

[0065] The linear actuator **104** moves between a first, initial position and a second, extended position. Placing the linear actuator **104** in the second, extended position moves the locking element **150** to a deployed position and couples the pocket plate **142** and notch plate **144**. When the linear actuator **104** is in the second, extended position the second cam member **108**, through the spring plate **146** and actuation springs **148**, causes the locking element **150** to couple the pocket plate **142** and notch plate **144**. When the linear actuator **104** is in the first, initial position, the return springs **147** push the first cam member **106** and second cam member **108** together, see FIGS. **8** and **12**, wherein the actuation springs **148** do not act on the locking elements **150** and the pocket plate **142** and notch plate **144** of the dynamically controllable clutch (DCC) **166** are decoupled. Consequently, when the linear actuator **104** is in the second, extended position, torque flow between components fixedly connected to the pocket plate **142** and the notch plate **144** is enabled.

[0066] The linear actuator **104** includes a cam mechanism. A cam mechanism usually consists of two moving elements mounted on a fixed frame, a cam, and a cam follower. The cam follower moves in a plane transverse to the axis of rotation of the cam.

[0067] The first cam member **106** is a rotating portion of a cylinder, with a cam face or cam surface **112** being one end of the cylinder. The first cam member **106** functions as the “cam,” it is rotatably movable but axially fixed. The second cam member **108** is an axially moving portion of a cylinder, with a cam face or cam surface **116** being one end of the cylinder. The second cam member **108** functions as the “cam follower,” it is rotatably fixed but axially movable. The second cam member **108** translates, moves axially in the longitudinal direction of the rotational axis **118**, whereas the cam or first cam member **106** rotates about the rotational axis **118**.

[0068] In one example, the linear actuator **104** functions as a two-position actuator. FIG. **10** shows the first cam member **106** with a cylindrical body **110** and a cam surface **112**. The cam surface **112** includes a base surface **120**, a projecting member or surface **122**, and ramps **124** between the base surface **120** and the projecting member or surface **122**. The projecting member or surface **122** extends or projects axially from the base surface **120**. FIG. **11** shows the second cam member **108** with a cylindrical body **114** with a cam surface **116**. The cam surface **116** includes a base surface **126**, a projecting member or surface **128**, and ramp **130** between the base surface **126** and the projecting member or surface **128**. The projecting member or surface **128** extends or projects axially from the base surface **126**. FIG. **12** shows the linear actuator **104** in a first, initial position. As shown, the projecting member or surface **128** of the second cam member **108** is positioned adjacent to the base surface **120** of the first cam member **106**. FIG. **13** shows the linear actuator **104** in a second, extended position. As shown, the projecting member or surface **128** of the second cam member **108** is positioned adjacent to the projecting member or surface **122** of the first cam member **106**.

[0069] To move the linear actuator **104** to the second, extended position, the first cam member **106** rotates in the direction of the arrow **132** about the rotational axis **118**. The interaction between cam surface **112** of the first cam member **106** and cam surface **116** of the second cam member **108** causes the second cam member **108** to move axially away from the first cam member **106** in the direction of the arrow **136**. The projecting member or surface **128** of the second cam member **108** moves up the ramp **124** of the first cam member **106** until it reaches and moves along the projecting member or surface **122** of the first cam member **106**, wherein the second cam member **108** moves axially away from the first cam member **106** a distance illustrated by the arrow **134**.

[0070] The linear actuator **104** may be used to control system components; for example, engagement when the actuator is in the second, extended position and disengagement when the actuator is in the first, initial position. To return or retract the linear actuator **104** to the first, initial position, the first cam member **106** rotates in an opposite or second direction, shown by the arrow **140**. The interaction between cam surface **112** of the first cam member **106** and cam surface **116** of the second cam member **108** enables the second cam member **108** to move axially toward the first cam member **106**. The second cam member **108** is externally biased by the return spring **147** to move axially toward the first cam member **106**.

[0071] In one example, the linear actuator **104** actuates a clutch assembly **102** between a first mode in which first and second coupling members of the clutch assembly **102** are coupled together and a second mode in which the first and second coupling members are not coupled together. The linear actuator **104** includes a first cam member **106** and a second cam member **108**. The first cam member **106** has a cam surface **112** rotatably movable and axially fixed, and the second cam member **108** has a cam surface **116** rotatably fixed and axially movable. The first cam member **106** and second cam member **108** are axially stacked together with the respective cam surfaces **112**, **116** facing each other. Rotation of the first cam member **106** and interaction of the cam surfaces **112**, **116** axially moves the second cam member **108** away from the first cam member **106**, placing the linear actuator **104** in the second, extended position. Placing the linear actuator **104** in the second, extended position moves the locking element **150** in a deployed position correspondingly coupling together the coupling members, for example, the pocket plate **142** and the notch plate **144** of the dynamically controllable clutch (DCC) **166**.

[0072] When the first cam member **106** rotates in the opposite direction, shown by the arrow **140**, the interaction between the respective cam surfaces **112**, **116** allows the spring force applied by the return springs **147** to move the second cam member **108** axially toward the first cam member **106** whereby the linear actuator **104** is in the first, initial position and the coupling members, the pocket plate **142** and the notch plate **144**, are not coupled together.

[0073] The first and second coupling members, the pocket plate **142** and the notch plate **144**, are supported for rotation relative to one another in first and second directions about a rotational axis. A locking element **150** moves between a deployed position, in which the locking element **150** mechanically couples the coupling members together to prevent relative rotation of the coupling members in at least one direction about the rotational axis, and a non-deployed position, in which the coupling members are not mechanically coupled together by the locking element **150** whereby the coupling members may rotate relative to one another in the first and second directions about the rotational axis.

[0074] Interaction of the cam surfaces **112**, **116** caused by rotation of the first cam member **106** in the direction of the arrow **132** axially moves the second cam member **108** away from the first cam member **106**, putting the linear actuator **104** in a second, extended position and moving the locking element **150** to a deployed position. Interaction of the cam surfaces **112**, **116** caused by rotation of the first cam member **106** in the opposite direction, direction of the arrow **140**, axially moves the second cam member **108** toward the first cam member **106**, putting the linear actuator **104** in the first, initial position wherein the locking element **150** is placed in the non-deployed position.

[0075] One example of the system includes first and second power components, such as a driveshaft and a driven shaft. The clutch assembly **102** includes first and second coupling members, for example, a pocket plate **142** and a notch plate **144**. The pocket plate **142** connects to the first power component, the driveshaft **184**, and the notch plate **144** connects to the second power component, the driven shaft **182**. The first and second coupling members are supported for rotation relative to one another in first and second directions about a rotational axis.

[0076] The clutch assembly **102** also includes a locking element **150** movable between a deployed position in which the locking element mechanically couples the coupling members together and a non-deployed position in which the coupling members, and correspondingly the power components are not mechanically coupled together.

[0077] A link or connecting element extends between the second cam member **108** and the locking element **150**. One example of a link or connecting element is the actuation spring **148** supported by the spring plate **146**. The link or connecting element transfers the axial movement of the second cam member **108** to the locking element **150**. When the linear actuator is in the second, extended position, the link or connecting element actuates the locking element **150**, moving it to the deployed position. Other examples of a link or connecting element include resilient members, rods, or shaped members.

[0078] FIGS. **14-30** show an alternative example of the system, including a clutch assembly **102** with a dynamically controllable clutch (DCC) **198** and a linear actuator, generally indicated at **200**. In each of the following embodiments, similar or identical elements are given consistent reference numerals throughout the various figures and indicate corresponding parts.

[0079] The dynamically controllable clutch (DCC) **198** typically includes a pocket plate **242**, a notch plate **244**, a first locking element **238**, and a second locking element **240**. In one example, the first and second locking elements **238**, **240** are in pockets **246** in the pocket plate **242**.

[0080] The linear actuator **200** includes a first cam member **202**, a second cam member or cam follower **204**, and a third cam member or cam follower **206**. The linear actuator **200** may also include inner and outer actuation members, for example, a first or outer spring plate **222**, having return springs **224** and actuation springs **226**, and a second or inner spring plate **228** having return springs **230** and actuation springs **232**. Positioned between the respective second cam member or cam follower **204** and third cam member or cam follower **206** and the first and second spring plates **222** and **228** are first and second thrust plates or bearing members **234**, **236**.

[0081] The dynamically controllable clutch (DCC) **198** provides a clutch assembly **102** that operates in four different modes, multiple connected states, or modes of torque transfer depending on how the first and second locking elements **238**, **240** are positioned; for example, deployed, extended, engaged, or non-deployed, retracted, nonengaged. The linear actuator **200** works with the dynamically controllable clutch (DCC) **198** to impose torque in the counterclockwise and clockwise directions. The following nomenclature (__/__) refers to rotation direction, clockwise and counterclockwise, for the dynamically controllable clutch (DCC) **198**, wherein the left side of the slash signifies torque imposition in the counterclockwise direction, and the right of the slash signifies torque imposition in the clockwise direction. As used herein, a numeral (**1**) on the left side of the slash indicates torque imposition in the counterclockwise direction. A numeral zero (0) on the left side of the slash indicates no torque imposition in the counterclockwise direction. The same convention, either a one (1), indicating torque imposition in the clockwise direction, or a zero (0), indicating no torque imposition in the clockwise direction, is used on the right side of the slash. The direction of torque imposition identifies a locked state or direction.

[0082] A first mode of the clutch assembly is configured as follows, dynamically controllable clutch (DCC) **198**-0/0. In this mode, the first locking element **238** and second locking element **240** of the dynamically controlled clutch (DCC) **198** are not deployed and are nonengaged. The first coupling or pocket plate **242** transmits no torque either clockwise or counterclockwise. Neither the first locking element **238** nor the second locking element **240** engages the second coupling or notch plate **244**, and the pocket plate **242** transmits no torque in either direction to the notch plate **244**. The notch plate **244** is free to rotate in both counterclockwise and clockwise directions with respect to the pocket plate **242**.

[0083] A second mode of the clutch assembly is configured as follows, dynamically controllable clutch (DCC) **198**-1/0. In this mode, the first locking element **238** of the dynamically controllable clutch (DCC) **198** is engaged. The second locking element **240** of the dynamically controllable clutch (DCC) **198** is nonengaged, wherein the pocket plate **242** transmits torque in one direction, for example, in the counterclockwise direction to the notch plate **244**, overruns the notch plate **244** in the clockwise direction, and the notch plate **244** overruns the pocket plate **242** in the counterclockwise direction when the speed of rotation ω.sub.244 of the driven member, notch plate **244**, in the counterclockwise direction is faster than the rotational speed ω.sub.242 of the driving member, pocket plate **242** in the counterclockwise direction.

[0084] A third mode of the clutch assembly is configured as follows, dynamically controllable clutch (DCC) **198**-0/1. In this mode, the first locking element **238** of the dynamically controllable clutch (DCC) **198** is nonengaged. The second locking element **240** of the dynamically controllable clutch (DCC) **198** is engaged wherein the pocket plate **242** transmits torque in one direction, for example, the clockwise direction, to the notch plate **244**, overruns the notch plate **244** in the opposite or counterclockwise direction, and the notch plate **244** overruns the pocket plate **242** in the clockwise direction when the speed of rotation ω.sub.244 of the driven member, notch plate **244**, in the clockwise direction is faster than the rotational speed ω.sub.242 of the driving member, pocket plate **242** in the clockwise direction.
[0085] A fourth mode of the clutch assembly is configured as follows, dynamically controllable clutch (DCC) **198**-1/1. In this mode, the locking elements **238**, **240** of the dynamically controllable clutch (DCC) **198** are both engaged, wherein the pocket plate **242** transmits torque in both the counterclockwise and clockwise directions to the notch plate **244**, and the notch plate **244** rotates with the pocket plate **242** in both directions.
[0086] The clutch assembly **102** of the system **100** further includes a clutch assembly housing **156**. The system **100** also includes a motor housing **168** for a motor **170**. The motor **170** includes a motor shaft **172**, a worm **174**, and an O-ring **176**. A gear assembly, seen generally at **250**, operates to rotate the first cam member **202**. The gear assembly **250** includes a plurality of gear teeth, for example, a ring gear **252** on an outer peripheral surface of the first cam member **202**. The ring gear **252** engages the worm **174**, whereby rotation of the motor **170** in either direction translates into rotational movement of the first cam member **202** about the rotational axis **118**. The motor **170** actuates the first cam member **202** of the linear actuator **200**, causing the first cam member **202** to rotate about the rotational axis **118**, in the directions shown by the arrows **132**, **140**. The linear actuator **200** actuates the dynamically controllable clutch **198** through all four modes. The first cam member **202** functions as the “cam,” it is rotatably movable but axially fixed. The second and third cam members **204**, **206** function as “cam followers,” they are rotatably fixed but axially movable.
[0087] The clutch assembly housing **156** includes an axially extending spindle **290** that rotatably supports the first cam member **202** in an annular aperture or recess **298**. An outer peripheral surface **292** of the spindle **290** engages and supports an inner peripheral surface **294** of the first cam member **202**, wherein the first cam member **202** rotates about the spindle **290**. An end face **296** of the first cam member **202** engages a shoulder or bearing face **300** of the annular aperture or recess **298** and limits axial movement of first cam member **202**. The return springs **224**, **230**, supported in sockets or seats **314** in the pocket plate **242**, act through the respective first and second spring plates **222**, **228** and first and second thrust plates or bearing members **234**, **236** on the second cam member or cam follower and third cam member or cam follower **204**, **206** to push or bias the end or face **296** of the first cam member **202** against the shoulder or bearing face **300** of the clutch assembly housing **156**. While the first cam member **202** rotates, it is constrained against axial motion.
[0088] The second cam member or cam follower **204** includes a plurality of outwardly extending projections, for example, ribs or ridges **302** that engage complementary grooves **304** in the clutch assembly housing **156**. The ribs or ridges **302** and complementary grooves **304** allow the second cam member or cam follower **204** to move axially but not rotationally. The ribs or ridges **302** slide axially in the grooves **304**. The third cam member or follower **206** includes a plurality of inwardly extending projections, for example, ribs or ridges **306** that engage complementary grooves **308** on the spindle **290**. The ribs or ridges **306** and complementary grooves **308** allow the third cam member or follower **206** to move axially but not rotationally. The first and second thrust plates or bearing members **234**, **236** provide a rotational interface and support between the respective second and third cam members or cam followers **204**, **206**, and the first and second spring plates **222**, **228**.
[0089] Referring to FIG. **18**, the cam profiles of the first cam surface **210** and the second cam surface **212** of the first cam member **202** may have a “wave” shape, pattern, or configuration. The

first cam surface **210** may include a base surface **254**, a projecting member or surface **256**, and ramps **258** extending between the base surface **254** and the projecting member or surface **256**. The second cam surface **212** may include a base surface **260**, a projecting member or surface **262**, and ramps **264** extending between the base surface **260** and the projecting member or surface **262**.

[0090] The cam or first cam member **202** is a rotating portion of a cylinder with the cam surfaces **210**, **212** being on one end of the cylinder. The first cam surface **210** and the second cam surface **212** are concentric circular surfaces on one end of the cylindrical body of the first cam member **202**. FIG. **18** shows the respective cam profile or configuration of each of the first and second cam surfaces **210**, **212** associated with each mode or position of the dynamically controllable clutch (DCC) **198**. As shown, each of the four positions is identified by the nomenclature 1/1, 0/1, 1/0, and 0/0 on the first cam member **202**. When the second and third cam members or cam followers **204**, **206** are positioned at the respective identified positions, the dynamically controllable clutch **198** is placed in the corresponding mode.

[0091] Referring to FIG. **19**, the second cam member or cam follower **204** has a cylindrical body **214** with a cam profile, cam face or cam surface **216**, on one end of the cylindrical body **214**. The cam face or surface **216** of the second cam member or cam follower **204** may have a “wave” shape, pattern, or configuration. The cam surface **216** may include a base surface **266**, a projecting member or surface **268**, and ramps **270** extending between the base surface **266** and the projecting member or surface **268**. The cam face or surface **216** of the second cam member or cam follower **204** engages and follows the first cam surface **210**.

[0092] Referring to FIG. **20**, the third cam member or cam follower **206** has a cylindrical body **218** with a cam profile, cam face or cam surface **220**, on one end of the cylindrical body **218**. The cam face or surface **220** of the third cam member or cam follower **206** may have a “wave” shape, pattern, or configuration. The cam surface **220** may include a base surface **272**, a projecting member or surface **274**, and ramps **276** extending between the base surface **272** and the projecting member or surface **274**. The cam face or surface **220** of the third cam member or cam follower **206** engages and follows the second cam surface **212**.

[0093] The first cam surface **210** and second cam surface **212** of the first cam member **202** are concentric surfaces. The first cam surface **210** of the first cam member **202** is axially stacked with the cam surface **216** of the second cam or cam follower **204**, and the second cam surface **212** of the first cam member **202** is axially stacked together with the cam surface **220** of the third cam **206**. Accordingly, the second cam or cam follower **204** and the third cam or cam follower **206** also have concentric cylindrical surfaces, with one of the surfaces inside the other. The second cam member or cam follower **204** and the third cam member or follower **206** move independently along the respective first and second cam surfaces **210**, **212** of the first cam member **202** as the first cam member **202** rotates. Rotation of the first cam member **202** and interaction of the respective cam surfaces **210**, **216**, **212**, **220** axially moves the second and third cams or cam followers **204**, **206** away from and toward the first cam member **202**. Moving the respective second and third cams or cam followers **204**, **206** places the linear actuator **200** in multiple positions.

[0094] The first cam member **202** has discreet positions, 0/0, 0/1, 1/0, and 1/1. The motor **170**, through the gear assembly **250**, rotates the first cam member **202** in either direction, shown by arrows **132**, **140**, to position the first cam member **202** in one of the positions, 0/0, 1/0, 0/1 and 1/1. Depending upon the selected position, interaction between the cam surfaces of the respective cam members **202**, **204**, **206**, the second cam member or cam follower **204** moves between an extended, locking element deployed position and an initial or retracted, locking element non-deployed position, while the third cam member or follower **206** moves between an extended, locking element deployed position and an initial or retracted, locking element non-deployed position. Based on the combination of the deployed and non-deployed positions, the first and second locking elements **238**, **240** mechanically couple the coupling members together.

[0095] In one example, the linear actuator **200** is a four-position actuator. The linear actuator **200** starts at the 0/0 mode and based on rotation and direction of the first cam member **202**, other modes or positions are achieved. The linear actuator **200** may also start at one of the other modes, for example the 1/1 mode. In addition, rather than modes 1/0 or 0/1 being adjacent to mode 0/0, mode 1/1 could be adjacent to mode 0/0.

[0096] FIGS. **21**, **22** show the linear actuator **200** in a 0/0 mode, with the second cam member or cam follower **204** and the third cam member or follower **206** in an initial or retracted position. The return springs **224**, **230**, which bias or urge the cam second and third cam members or cam followers **204**, **206** and first cam member **202** together, are removed for clarity, with the actuation springs **226**, **232** shown. In the first or initial position, the 0/0 mode, the first and second locking elements **238**, **240** are in the non-deployed position, as both cam followers **204** and **206** of the linear actuator **200** are in the initial or retracted position. As illustrated in FIG. **22**, in the initial or retracted position, the projecting members or surfaces **268**, **274** of each of the second cam member or cam follower **204** and third cam member or follower **206** are located at the base **254**, **260**, of each of the first and second cam surfaces **210**, **212**. The actuation springs **226**, **232** are in an initial, retracted position where they do not act on and deploy the locking elements **238**, **240**.

[0097] FIGS. **23**, **24** illustrate the linear actuator **200** in a 1/0 mode. The second cam member or cam follower **204**, the outer concentric ring, is positioned in an extended position. To achieve the 1/0 mode, the first cam member **202** is rotated clockwise, in the direction of the arrow **132**, until the first projecting member or surface **256** of the first cam surface **210** of the first cam member **202** is adjacent or contacts the projecting member or surface **268** of the second of the cam surface **216** of the second cam or cam follower **204** thereby extending or moving the second cam or cam follower **204** axially with respect to the first cam member **202**. Moving the second cam or cam follower **204** axially moves the first thrust plate or bearing member **234**, the first spring plate **222**, and actuation spring **226** axially, wherein the actuation spring **226** acts on the first locking element **238**, placing it in a deployed position. Rotating the first cam member **202** in the clockwise direction, arrow **132**, moves the linear actuator **200** from the 0/0 mode to the 1/0 mode. When rotating the first cam member **202** in the clockwise direction, shown by the arrow **132**, the projecting member or surface **274** of the third cam member or follower **206**, inner concentric ring, follows along the second cam surface **212** and remains on the base **260**. The actuation spring **232** of the second spring plate **228** remains in the initial, retracted position where it does not act on and deploy the locking element **240**.

[0098] FIGS. **25**, **26** illustrate the linear actuator **200** in a 0/1 mode. The third cam member or follower **206**, the inner concentric ring, is positioned in an extended position. To achieve the 0/1 mode, the first cam member **202** rotates counterclockwise in the direction of the arrow **140**, from the 0/0 mode until the projecting member or surface **262** of the second cam surface **212** of the first cam member **202** is adjacent or contacts the projecting member or surface **274** of the cam surface **220** of the third cam or cam follower **206** extending or moving the third cam or cam follower **206** axially with respect to the first cam member **202**. In this position, the projecting member or surface **274** of the cam surface **220** of the third cam or cam follower **206** is adjacent or placed on the projecting member or surface **262** of the second cam surface **212** of the first cam member **202**. Moving the third cam or cam follower **206** axially moves, through the second thrust plate or bearing member **236**, the second spring plate **228** and actuation spring **232** in the axial direction wherein the actuation spring **232** acts on the second locking element **240** moving it to a deployed position. Rotating the first cam member **202** in the counterclockwise direction, arrow **140**, moves the linear actuator **200** from the 0/0 mode to the 0/1 mode. When rotating the first cam member **202** in the counterclockwise direction, the projecting member or surface **268** of the second cam member or cam follower **204**, outer concentric ring, follows the second cam surface **212** and remains on the base **254**. The actuation spring **232** of the second spring plate **228** is in the initial or retracted position where it does not act on or deploy the locking element **238**.

[0099] FIGS. **27**, **28** illustrate the linear actuator **200** in a 1/1 mode. The second cam member or cam follower **204** and the third cam member or follower **206**, the outer and inner concentric rings, are positioned in the extended position. To achieve the 1/1 mode, the first cam member **202** rotates either clockwise or counterclockwise from the 0/0 mode, through either the 1/0 or 0/1 modes until the first projecting member or surface **256** of the first cam surface **210** of the first cam member **202** is adjacent or contacts the projecting member or surface **268** of the second cam surface **216** of the second cam or cam follower **204** extending or moving the second cam or cam follower **204** axially with respect to the first cam member **202** and the projecting member or surface **262** of the second cam surface **212** of the first cam member **202** is adjacent or contacts the projecting member or surface **274** of the cam surface **220** of the third cam or cam follower **206** extending or moving the third cam or cam follower **206** axially with respect to the first cam member **202**.

[0100] Moving the second cam or cam follower **204** axially correspondingly moves, through the first thrust plate or bearing member **234**, the first spring plate **222** and actuation spring **226** in the axial direction wherein the actuation spring **226** acts on the first locking element **238**, moving it to a deployed position. Moving the third cam or cam follower **206** axially correspondingly moves, through the second thrust plate or bearing member **236**, the second spring plate **228** and actuation spring **232** in the axial direction wherein the actuation spring **232** acts on the second locking element **240** moving it to a deployed position. With both the first and second locking elements **238**, **240** in a deployed position, the first coupling member or pocket plate **242** is coupled in both directions to the second coupling member or notch plate **244** by the locking elements **238**, **240** extending from pockets **246** in the pocket plate and engaging notches **248** in the notch plate **244**. Because the first coupling member or pocket plate **242** and second coupling member or notch plate **244** are connected to respective power components, for example, a driveshaft **184** and a driven shaft **182**, coupling the pocket plate **242** to the notch plate **244** couples the driveshaft **184** and driven shaft **182** enabling power or torque transfer from the drive shaft to the driven shaft.

[0101] FIG. **29** shows an outer actuation member for example, the first spring plate **222**, having an annular configuration, and an inner actuation member for example, the second spring plate **228** having an annular configuration. The outer actuation member is concentric with the inner actuation member. While the respective first spring plate **222** and second spring plate **228** are inner and outer members spaced from one another, the actuation springs **226** and **232** are on the same radius, the same radial distance from the rotational axis **118**. As illustrated, the first spring plate **222** includes inwardly extending tabs **280**. The second spring plate **228** includes outwardly extending tabs **282** that extend into complementary notches **284** located in the inner circumferential surface **286** of the first spring plate **222**. The respective inwardly extending tabs **280** and outwardly extending tabs **282** provide spring seats for the respective actuation springs **226** and **232**.

[0102] The actuation spring **226** operates as link element connecting or linking the second cam member or cam follower **204** with one of the first and second locking elements **238**, **240** and the actuation spring **232** operates as a link element connecting or linking the third cam member or cam follower **206** with the other of the first and second locking elements **238**, **240**. In addition, the first and second spring plates **222**, **228** may also operate as link elements. These are but one example of link elements that may be used to connect or link the second and third cam members or cam followers **204**, **206** with the first and second locking elements **238**, **240**. Other examples of a link or connecting element include resilient members, rods, or shaped members that transfer the axial motion of the second and third cam members or cam followers **204**, **206** to the respective first and second locking elements **238**, **240** to control the position of the first and second locking elements **238**, **240**. In some instances, the axial motion produced by the linear actuator **200** may be used to move one of the locking elements **238**, **240** from a deployed to a non-deployed position.

[0103] FIG. **30** discloses another alternative embodiment of the linear actuator **200**, wherein the linear actuator **200** is a three-position actuator. The three positions are 0/0, 1/1, and 1/0. Like the four-position actuator, the three-position actuator **402** uses a first cam member **404** having a first cam surface **406** and a second cam surface **408**. The cam surfaces **406**, **408** of the three-position actuator **402** include projections and bases. Like the previous embodiment, a second cam or cam follower and a third cam or cam follower cooperate with the first cam member **404** to move the first and second coupling members between a deployed and non-deployed position. The three-position actuator **402** may be placed initially in the 1/0 mode, wherein rotation in either direction places the actuator **402** in either the 0/0 mode or the 1/1 mode. The 1/0 mode could be used to actuate a locking element to transfer torque in either the clockwise or counterclockwise direction.

[0104] FIGS. **31-33** illustrate another example of a cam member, seen generally at **500**, for use with an actuator. The cam member **500** has a cylindrically shaped body **502** extending along a longitudinal axis **504**. The cylindrically shaped body **502** includes an outer peripheral surface **506** and an inner peripheral surface **508**. The cylindrically shaped body **502** includes an end surface **510** extending between the outer peripheral surface **506** and the inner peripheral surface **508**. A plurality of gear teeth **512**, for example, a ring gear, are located on the outer peripheral surface **506**. The gear teeth **512** engage another gear member, for example, a worm gear, wherein the worm gear operates in conjunction with the gear teeth **512** to rotate the cam member **500** about the longitudinal axis **504** in either direction, shown by arrows **528**, **530**.

[0105] The cam member **500** includes a first cam surface **514** on the end surface **510** and a second cam surface **516** on the outer peripheral surface **508**. The first cam surface **514**, is a longitudinal cam surface, wherein the cam surface varies in the longitudinal or axial direction, the direction of the longitudinal axis **504**. The second cam surface **516**, is a radial cam surface, wherein the cam surface varies in the radial direction, a direction transverse to the direction of the longitudinal axis **504**. In the example of FIG. **31**, the second cam surface **516** is formed by a base or lower surface **518**, extending between first and second sidewalls **520**, **522**, of a circumferential groove or notch **524** in the outer peripheral surface **508**.

[0106] Similar to the foregoing examples, both the first and second cam surfaces **514**, **516** of the cam member **500** have discreet positions identified as **0** and **1**. The motor, through the gear teeth **512**, rotates the first cam member **500** in either direction, shown by arrows **528**, **530**, to position the first cam member **500** in one of the positions, 0/0, 1/0, 0/1 and 1/1. Depending upon the selected position, the interaction between the cam surfaces **514**, **516** of the cam member **500**, a first cam follower **532**, associated with the first cam surface **514**, and a second cam follower **534**, associated with the second cam surface **516**, causes the respective locking elements **542**, **548** to move between an initial or retracted, locking element non-deployed position and an extended, locking element deployed positions. Based on the combination of the deployed and non-deployed positions, the first and second locking elements **542**, **548** mechanically couple the coupling members together, for example, notch plates **550**, **551** and a pocket plate **552**. In one example, the pocket plate **552** connects to the first power component, for example, a driveshaft **558**, and the notch plate **550** connects to the second power component, for example, a driven shaft **560**. The pocket plate also connects the first power component, the driveshaft **558**, to a stationary member or housing **551**. The first and second locking elements **542**, **548** part of a controllable clutch assembly used to couple different members. Including, in one example, a rotary member to a rotary member and/or a rotary member to a stationary member. In addition, while shown with a single locking elements **542**, **548** multiple locking elements can be used. The multiple locking elements may also include locking elements acting in both directions of rotation. For example, two longitudinal locking elements controlled by the first cam surface **514**. The two locking elements acting couple the members in either direction, shown by arrows **528**, **530**. In addition, there may be two radial locking elements controlled by the second cam surface. Again, radial locking elements acting couple the members in either direction, shown by arrows **528**, **530**.

[0107] As shown in FIG. **32**, the cam member **500** acts on the first cam follower **532**. The first cam follower **532** includes a thrust plate or portion **536**, engaging a spring plate **538**. An actuation member, for example, an actuation spring **540**, extends between the spring plate and the locking element **542**.

[0108] The cam member **500** also acts on the second cam follower **534**. The second cam follower **534** includes a tappet **544**, for example, a lever or member, engaging the second cam surface **516**. The tappet **544** acts on an actuation member, for example, an actuation spring **546**, extending between the tappet **544** and the locking element **548**.

[0109] Depending upon the position of the cam member **500**, interaction between the cam surfaces **514**, **516** and the respective cam followers **532**, **534** move the locking elements **542**, **548** between an extended, locking element deployed position and an initial or retracted, locking element non-deployed position.

[0110] As illustrated in FIGS. **32** and **33**, the first locking element **542** moves in an axial direction, in the direction of the longitudinal axis **504**, and the second locking element **548** moves in a radial direction, a direction transverse to the longitudinal axis **504**.

[0111] Similar to the previous embodiments, the axially moving locking element **542** and the radially moving locking element **548** are independently controlled to place the actuator in multiple modes. FIG. **32** illustrates the linear actuator in a 1/1 mode wherein the cam member **500** is rotated to a position such that each of the locking elements **542**, **548** are placed in an extended locking element deployed position. A projection or projecting surface **554** on the first cam surface **514**, associated with mode 1, contacts the thrust plate or portion **536** of the first cam follower **532** and extends or moves the first cam follower **532** and thrust plate or portion **536**, the spring plate **538**, the actuation spring **540** longitudinally, wherein the actuation spring **540** acts on the first locking element **542** placing it in a deployed position. The cam follower **532** may have a complementary configuration, for example, a corresponding projection or projecting surface, wherein when the two coincide and are opposed to one another they move the first cam follower **532**. Similar to the first cam surface **514**, the second cam surface **516** includes a projection or projecting surface **556** associated with mode 1. The projection or projecting surface **556** of the second cam surface **516** contacts the tappet **544** and extends or moves the tappet **544** radially outward, wherein the actuation spring **546** acts on the second locking element **548** and places it in a deployed position.

[0112] FIG. **33** illustrates the actuator in a 0/0 mode with the first and second cam followers **532**, **534** in an initial or retracted position. In the 0/0 mode, the cam member **500** is rotated to a position such that the locking elements **542**, **548** are placed in a retracted, nondeployed position. The thrust plate or portion **536** of the first cam follower **532** contacts a valley or depression **562**, associated with mode 0, of the first cam surface **514**. The tappet **544** of the second cam follower **534** contacts a valley or depression **564**, associated with mode 0, of the second cam surface **516**. When the actuator is in a 0/0 mode, the cam followers **532**, **534** fit in respective valleys or depressions **562**, **564** the first and second cam surfaces **514**, **516**.

[0113] The actuator may also include return springs. The return springs bias the first and second cam followers toward the first and second cam surfaces **514**, **516**. The return springs may act directly on the first and second cam followers **532**, **534**. They may also act through the first and second locking elements **542**, **548**. For example, the return springs act on the respective locking elements to bias or urge the locking elements to a nondeployed position. As illustrated, in the 0/0 mode, the first and second locking elements **542**, **548** are in the non-deployed position as both the first and second cam followers **532**, **534** are in the initial or retracted position. As illustrated, the surfaces of the first and second cam followers **532**, **534** are located at the valley or depression **630**, **640** of each of the first and second cam surfaces **514**, **516**. The actuation springs **540**, **546** are in an initial, retracted position where they do not act on and deploy the locking elements **542**, **548**.

[0114] Similar to previous examples, the cam member **500** may place the actuator in a 1/0 mode wherein only the first locking element **532**, associated with the axial or first cam surface **514**, is deployed or in a 0/1 mode and wherein only the second locking element **548**, associated with the second or radial cam surface **516** is deployed. The 1 and 0 mode numbers are illustrated on the respective first and second cam surfaces **514**, **516** as examples of respective cam modes and are not required for actuator operation.

[0115] FIGS. **34-37**B illustrate another example of a cam member **600** for use with an actuator operative to move locking elements between a first deployed position and a second nondeployed position. Similar to the previous embodiment, the cam member **600** has a cylindrically shaped body **602** extending along a longitudinal axis **604**. The cylindrically shaped body **602** includes an outer peripheral surface **606** and an inner peripheral surface **608**. The cylindrically shaped body **602** includes an end surface **610** extending between the outer peripheral surface **606** and the inner peripheral surface **608**. A plurality of gear teeth **612**, for example, a ring gear, are located on the outer peripheral surface **606**. The gear teeth **612** engages another gear member, for example, a worm gear, wherein the worm gear operates in conjunction with the gear teeth **612** to rotate the cam member **600** about the longitudinal axis **604** in either a first direction **660** or a second direction **662**.
[0116] The cam member **600** includes a first cam surface **614** and a second cam surface **616** on the outer peripheral surface **608**. The first and second cam surfaces **614**, **616** are radial cam surfaces. The cam surfaces vary in the radial direction, the direction transverse to the direction of the longitudinal axis **604**. For example, the first and second cam surfaces **614**, **616** are formed by first and second circumferential grooves or notches **618**, **620** extending about the outer peripheral surface **608**. The first groove or notch **618** includes a base or lower surface **622** extending between first and second sidewalls **624**, **626**. The base or lower surface **622** forms the first cam surface **614**. The first cam surface **614** radially undulates. It includes radial projections or projecting surfaces **628** and valleys or depressions **630**. Similar to the first groove or notch **618**, the second groove or notch **620** includes a base or lower surface **632** extending between first and second sidewalls **634**, **636**. The base or lower surface **632** of the second groove or notch **620** forms the second cam surface **616**. The second cam surface **616** radially undulates. It includes radial projections or projecting surfaces **638** and valleys or depressions **640**.
[0117] The motor rotates the cam member **600** about the longitudinal axis **604** in either the first or second direction **660**, **662** wherein first and second cam followers **642**, **644** follow the first and second cam surfaces **614**, **616** to move the respective first and second locking elements **646**, **648** between an initial or retracted, locking element nondeployed position and an extended, locking element deployed position. Similar to the foregoing examples, the cam member **600** has discreet positions 0/0, 0/1, 1/0, and 1/1. In one example, 0 is associated with a valley, and 1 is associated with a projection.
[0118] FIG. **35** shows the first cam follower **642** is located in a valley or depression **630** of the first cam surface **614**, wherein the first locking element **646** is in the nondeployed position. The second cam follower **644** is located on a projection or projecting surface **638** of the second cam surface **616**, wherein the second locking element **648** is in the deployed position. The example of FIG. **35** shows the actuator in a 0/1 position, the locking element **646** is nondeployed, and the locking element **648** is deployed. As with the previous examples, the position of the cam member **600** and corresponding first and second cam surfaces **614**, **616** repositions the projections or projecting surfaces **628**, **638** and or depression of the respective cam surfaces **614**, **616** to place the actuators in the different modes. For example, if the first and second cam followers **642**, **644** are on the respective projections or projecting surfaces **628**, **638** of the first and second cam surfaces **614**, **616**, the actuator is positioned in a 1/1 mode wherein both the first and second locking elements **646**, **648** are deployed.
[0119] FIGS. **36** and **37**A-**37**B schematically illustrate other examples of the first and second cam followers **642**, **644**. FIG. **36** illustrates one example of the first cam follower **642** including a roller **650** engaging and following the valley or depression **630** of the first cam surface **614**. A plunger **652** is pivotably or rotatably connected to the roller **650**. The plunger **652** engages the first locking element **646** and biases the first locking element **646** radially outward into engagement with a notch **654** in the notch plate **664** when the roller **650** engages the projection or projecting surface **628** of the first cam surface **614**. The projection or projecting surface **628** causes the plunger **652** to

move radially outward and reposition the first locking element **646** into a deployed position. FIGS. **37-37**B schematically illustrate side views of alternative examples of the first cam follower **642**. The first cam follower **642**, shown in FIG. **37**B includes an actuation spring **658** connected on one end to the plunger **652** and engaging the first locking element **646** on the opposite end. Accordingly, as the plunger **652** moves radially outward, the spring **658** acts on the first locking element **646**. The same or similar structures may be used for the second cam follower **644** to act on and reposition the second locking element **648** into a deployed position, wherein it engages a notch **655** in the notch plate.

[0120] As with the foregoing example, based on the combination of the deployed and non-deployed positions, the first and second locking elements **642 648** mechanically couple the coupling members together, for example, a notch plate **664** and a pocket plate **666**. The pocket plate **666** connects to the first power component, for example, a driveshaft **668**, and the notch plate **664** connects to the second power component, for example, a driven shaft **670**.

[0121] FIGS. **38-40** illustrate another example of a cam member **700** for use with an actuator operative to move locking elements between a first deployed position and a second nondeployed position. Like previous examples, the cam member **700** has a cylindrically shaped body **702** extending along a longitudinal axis **704**. The cylindrically shaped body **702** includes an outer peripheral surface **706** and an inner peripheral surface **708**. The cylindrically shaped body **702** includes an end surface **710** extending between the outer peripheral surface **706** and the inner peripheral surface **708**. A plurality of gear teeth **712**, for example, a ring gear, are located on the outer peripheral surface **606**. The gear teeth **712** engage another gear member, for example, a worm gear. The worm gear operates in conjunction with the gear teeth **712** to rotate the cam member **700** about the longitudinal axis **704** in either a first direction **760** or a second direction **762**.

[0122] The cam member **700** includes a first cam surface **714** on the end surface **710** and a second cam surface **716** on the outer peripheral surface **706**. The first cam surface **714** is a longitudinal cam surface, wherein the cam surface varies in the longitudinal or axial direction, the direction of the longitudinal axis **704**. In one example the first cam surface **714** includes a longitudinally extending projection or projecting surface **718** in between adjacent valleys or depressions **720**. The second cam surface **716** is part of a circumferential groove or notch **722** in the outer peripheral surface **706**. As shown in FIG. **38**, the circumferential groove or notch **722** includes a base **724** extending between first and second sidewalls **726**, **728** of the circumferential groove or notch **722**. In one example, the second sidewall **728** forms the cam surface **716**, with the second sidewall **728** shifting longitudinally in the direction of the longitudinal axis **704**. In one example the second cam surface **714** includes a longitudinally extending projection or projecting surface **756** in between adjacent depressions or valleys **758**.

[0123] Depending upon the selected position of the cam member **700**, the interaction between the cam surfaces **714**, **716** of the cam member **700** and a first cam follower **730**, associated with the first cam surface **714**, and a second cam follower **732**, associated with the second cam surface **716**, respective first and second locking elements **734**, **736** move between an initial or retracted, locking element non-deployed position and an extended, locking element deployed positions. Based on the combination of the deployed and non-deployed positions, the first and second locking elements **734**, **736** mechanically couple the coupling members together, in one example, a notch plate **780** and a pocket plate **782**.

[0124] Similar to the example shown in FIG. **32**, as shown in FIG. **40** the cam member **700** acts on the first cam follower **730**. The first cam follower **730** includes a thrust plate or portion **738**, engaging a spring plate **740**. An actuation member, for example, an actuation spring **742**, extends between the spring plate **740** and the first locking element **734**. When the first cam follower **730** contacts a projection or projecting surface **718** on the first cam surface **714**, the thrust plate or portion **738** of the first cam follower **730** extends or moves the first cam follower **730**, including thrust plate or portion **738**, the spring plate **740**, and the actuation spring **742** wherein the actuation spring **742** acts on the first locking element **734** placing it in a deployed position. When the first cam follower **730** contacts the valley or depression **720** on the first cam surface **714**, the first locking element **734** is placed in a nondeployed position.

[0125] FIG. **39** shows one example of the second cam follower **732**, including an annular member **750**, a plurality of legs **752**, and a plurality of rollers **754**. The rollers **754** connect to and extend radially inward from the legs **752**. As shown in FIG. **40** the rollers **754** are located in the circumferential groove or notch **722** and engage the corresponding projection or projecting surface **756** of the second sidewall **728** and the valley or depression **768** on the opposed first sidewall **726**, wherein the annular member **750** and a spring plate **774** act on an actuation member, for example, an actuation spring **772** and places the second locking element **736** in a deployed position. Rotation of the cam member **700** in either the first direction or the second direction **760**, **762** moves the second cam follower **732** in the longitudinal direction and correspondingly moves the second locking element **736** between a deployed position and a nondeployed position.

[0126] While the first sidewall **726** acts as a cam surface, the projection or projecting surface **770** acts with the valley **758** wherein the rollers **754** and the annular member **750** move rearward and correspondingly move the second locking elements **736** to a nondeployed position. In another example, a return spring could also act on the annular member **750** or spring plate **740** to move the second cam follower **732** in a rearward direction, toward the gear teeth **712**, and keep the rollers **754** in contact with the second sidewall **728**. In this instance, the second sidewall **728** is the second cam surface **716**.

[0127] Similar to the previous embodiment, the motor rotates the cam member **700** about the longitudinal axis **704** in either the first or second direction **760**, **762**, wherein first and second cam followers **730**, **732** follow the first and second cam surfaces **714**, **716** to move the respective first and second locking elements **734**, **736** between an initial or retracted, locking element nondeployed position and an extended, locking element deployed position. The cam member **700** has discreet positions 0/0, 0/1, 1/0, and 1/1 wherein, in one example, 0 is associated with a valley **758**, and 1 is associated with a projection or projecting surface **756**.

[0128] FIG. **40** shows the first cam follower **730** located adjacent to a projection or projecting surface **718** of the first cam surface **714**, wherein the first locking element **734** is in a deployed position. The second cam follower **732** is located on a projection or projecting surface **756** of the second sidewall **728**, wherein the second locking element **736** is in the deployed position. FIG. **40** shows the actuator in a 1/1 position wherein both the first and second locking elements **734**, **736** are deployed. As with the previous examples, the position of the cam member **700** and corresponding first and second cam surfaces **714**, **716** in relation to the cam followers **730**, **732** place the actuator in other modes.

[0129] As with the foregoing examples, based on the combination of the deployed and non-deployed positions, the first and second locking elements **734**, **736** mechanically couple the coupling members together, for example, a notch plate **780** and a pocket plate **782**. The pocket plate **782** connects to the first power component, for example a driveshaft **784**, and the notch plate **70** connects to the second power component, for example a driven shaft **786**.

[0130] The cam members of the foregoing examples operate to translate the rotary motion of the respective cam members about the longitudinal axis into longitudinal or radial motion of respective cam followers. The cam followers then act to assist in positioning the locking elements in a deployed or nondeployed position.

[0131] While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms of the present invention. The words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the present invention. Additionally, the features of various implementing embodiments may be combined to form further embodiments of the present invention.

[0132] The description of the invention is merely exemplary in nature; thus, variations that do not depart from the gist of the invention are intended to be within the scope of the invention. Such variations are not to be regarded as a departure from the spirit and scope of the invention.

Claims

1. An actuation mechanism comprising: a cam member including a first cam surface and a second cam surface; the second cam surface spaced from the first cam surface, a first cam follower, first cam follower following the first cam surface; a second cam follower, the second cam follower following the second cam surface; a first link between the first cam follower and a first coupling member; and a second link between the second cam follower and a second coupling member.
2. The actuation mechanism of claim 1 wherein: the first cam surface is a longitudinal cam surface varying in a direction parallel to a rotational axis of the cam member; and the second cam surface is a longitudinal cam surface varying in a direction parallel to the rotational axis of the cam member.
3. The actuation mechanism of claim 2 wherein: the first cam follower is rotatably fixed and axially movable relative to the rotational axis, the first cam follower contacting and following the first cam surface; and the second cam follower is axially movable relative to the rotational axis, the second cam follower contacting and following the second cam surface.
4. The actuation mechanism of claim 1 wherein: the first cam surface and the second cam surface are spaced concentrically.
5. The actuation mechanism of claim 1 wherein: the first cam surface and the second cam surface are spaced longitudinally on the cam member.
6. The actuation mechanism of claim 1 wherein: the first cam surface is a longitudinal cam surface varying in a direction parallel to a rotational axis of the cam member; and the second cam surface is a radial cam surface varying in a direction transverse to a rotational axis of the cam member.
7. The actuation mechanism of claim 6 wherein: the first cam follower is rotatably fixed and axially movable relative to the rotational axis, the first cam follower contacting and following the first cam surface; and the second cam follower is rotatably fixed and radially movable relative to the rotational axis, the second cam follower contacting and following the second cam surface.
8. The actuation mechanism of claim 6 wherein: the first cam surface and the second cam surface are spaced longitudinally on the cam member.
9. The actuation mechanism of claim 1 wherein: the first cam surface is a radial cam surface varying in a direction transverse to a rotational axis of the cam member; and the second cam surface is a radial cam surface varying in a direction transverse to a rotational axis of the cam member.
10. The actuation mechanism of claim 9 wherein: the first cam follower is radially movable relative to the rotational axis, the first cam follower contacting and following the first cam surface; and the second cam follower is radially movable relative to the rotational axis, the second cam follower contacting and following the second cam surface.
11. The actuation mechanism of claim 9 wherein: the first cam surface and the second cam surface are spaced longitudinally on the cam member.
12. The actuation mechanism of claim 1 wherein the first cam follower and the second cam follower move independently.
13. An actuator comprising: a cam member rotatable about a rotational axis, the cam member having a end surface extending between an outer peripheral surface and an inner peripheral surface; the cam member having a first cam surface and a second cam surface; the first cam surface having a cam profile; the second cam surface having a cam profile; a first cam follower following the cam profile of the first cam surface wherein the first cam follower moves between an extended position and a retracted position based on the cam profile of the first cam surface; and a second cam follower following the cam profile of the second cam surface, wherein the second cam follower

moves between an extended position and a retracted position based on the cam profile of the second cam surface.

14. The actuator of claim 13 including: the cam profile of the first cam surface is on the end surface; and a groove in the outer peripheral surface of the cam member, a sidewall of the groove forming the second cam surface.

15. The actuator of claim 13 including: the cam profile of the first cam surface is on the end surface; and a groove in the outer peripheral surface of the cam member, a base of the groove forming the second cam surface.

16. The actuator of claim 13 including: a first groove in the outer peripheral surface of the cam member, the first groove including the cam profile of the first cam surface; and a second groove spaced from the first groove, the second groove including the cam profile of the second cam surface.

17. The actuator of claim 13 wherein: the first cam follower is connected to and moves a first locking element, and the second cam follower is connected to and moves a second locking element.

18. A system comprising: a first component; a second component; first and second coupling members supported for rotation relative to one another in first and second directions about a rotational axis, the first coupling member fixed to the first component and the second coupling member fixed to the second component; a first locking element movable between a deployed position in which the first locking element mechanically couples the first and second coupling members together and a non-deployed position in which the first and second coupling members are not mechanically coupled together; a second locking element movable between a deployed position in which the second locking element mechanically couples the first and second coupling members together and a non-deployed position in which the first and second coupling members are not mechanically coupled together; an actuator including a cam member rotatably movable and axially fixed relative to the rotational axis, the cam member having a first cam surface and a second cam surface, the first cam surface spaced from the second cam surface; a first cam follower movable relative to the rotational axis, the first cam follower contacting and following the first cam surface; a second cam follower movable relative to the rotational axis, the second cam follower contacting and following the second cam surface; and the cam member moves the first and second cam followers to a first position wherein both the first and second cam followers are extended, a second position wherein both the first and second cam followers are retracted, and a third position wherein one of the first cam follower and the second cam follower is extended and the other cam follower is retracted.

19. The system of claim 18 wherein: the first cam surface is longitudinally spaced from the second cam surface on the cam member, each of the first cam surface and the second cam surface is a longitudinal cam surface wherein the first and second cam followers move longitudinally relative to the rotational axis.

20. The system of claim 18 wherein: the first cam surface is longitudinally spaced from the second cam surface on the cam member, the first cam surface is a longitudinal cam surface and the second cam surface is a radial cam surface wherein the first cam follower moves longitudinally relative to the rotational axis and the second cam follower moves radially relative to the rotational axis.

21. The system of claim 18 wherein: the first cam surface is longitudinally spaced from the second cam surface on the cam member, the first cam surface is a radial cam and the second cam surface is a radial cam surface wherein the first cam follower moves radially relative to the rotational axis and the second cam follower moves radially relative to the rotational axis.