EXPANDING FORCE ELECTRIC LINEAR ACTUATOR

Abstract

In general, this disclosure involves a pulley system that includes a plurality of fixed sheaves arranged to at least partially encircle an output shaft, a plurality of traveling sheaves coupled to the output shaft. The output shaft can be configured to pass through the fixed sheaves and translate along an axis of travel and the plurality of traveling sheaves can be arranged such that a geometric average of belt tension created by spans of belt between the plurality of traveling sheaves and the plurality of fixed sheaves is approximately coincident with a centerline of the output shaft. The system further includes a belt extending between and around the plurality of fixed sheaves and the plurality of traveling sheaves such that the belt flexes toward a single surface of the belt.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] This application is a continuation of U.S. patent application Ser. No. 18/436,624, filed Feb. 8, 2024, the contents of which are hereby incorporated by reference in its entirety.

TECHNICAL FIELD
[0002] This disclosure generally relates to a pulley system arranged to enable expansion of an electrically driven linear actuator.
BACKGROUND
[0003] Modern belts have many desirable characteristics. They can be lightweight, low-maintenance, and have high strength under tension. Many new and old applications of modern belts are currently being adapted.
SUMMARY
[0004] In general, the disclosure involves a pulley system and method of use that includes a plurality of fixed sheaves arranged to at least partially encircle an output shaft, a plurality of traveling sheaves coupled to the output shaft. The output shaft can be configured to pass through the fixed sheaves and translate along an axis of travel and the plurality of traveling sheaves can be arranged such that a geometric average of belt tension created by spans of belt between the plurality of traveling sheaves and the plurality of fixed sheaves is approximately coincident with a centerline of the output shaft. The system further includes a belt extending between and around the plurality of fixed sheaves and the plurality of traveling sheaves such that the belt flexes toward a single surface of the belt.
[0005] Implementations can optionally include one or more of the following features.
[0006] In some instances, the plurality of fixed sheaves includes six sheaves arranged in pairs on three axles that are mounted to a device casing, one pair of sheaves is arranged such that the sheave positioned farther from the output shaft is smaller in diameter than the sheave positioned closer to the output shaft. Two pairs of sheaves are arranged such that the sheaves positioned farther from the output shaft are larger in diameter than the sheaves positioned closer to the output shaft.
[0007] In some instances, the plurality of fixed sheaves are retained on the three axles by a set of flanged end caps that are each bolted to the device casing through a center of their respective axle.
[0008] In some instances, two additional belt spans each exit the larger sheaves on the two pairs of sheaves arranged such that the larger diameter sheave is positioned farther from the output shaft and are positioned externally to the device casing.
[0009] In some instances, the plurality of traveling sheaves includes five sheaves coupled to an end of the output shaft.
[0010] In some instances, the belt forms at least ten spans between the plurality of traveling sheaves and the plurality of fixed sheaves.
[0011] In some instances the pulley system is at least partially enclosed by the device casing, and the device casing is cylindrical.
[0012] This disclosure describes a pulley system that enables extension and contraction of a linear actuator under an expanding force and is configured to fit around the output shaft of that linear actuator. Belt driven systems can have many advantages over other similar systems. For example, a belt driven linear actuator can require less maintenance, be lighter weight, and be capable of more cycles than a similar hydraulic linear actuator. Further the belt driven system, when operated by an electric motor is capable of recouping energy during some movement events (e.g., lowering a load). Many belt drive mechanisms include a capstan, which can receive one or more turns or partial turns

of a belt and provide rotational force to draw/take in or pay out the belt. The capstan can be powered by, for example, an electric motor via a set of reduction gears or a hydraulic motor, among other things. The belt can be drawn/taken in or payed out to and from various pulley systems within the linear actuator.

[0013] To improve durability and maximum capacity of a belt-driven actuator, the internal pulley system can be designed with certain parameters. In general, belt wear and stress will be a limiting factor, and can be reduced by reducing (e.g., minimizing) the amount of bend the belt is subjected to. At the same time, the overall size and shape of the actuator can be similar to the form factor of conventional actuators such as hydraulic pistons. Therefore, this disclosure describes a pulley system that is capable of handling large loads while maintaining an approximately cylindrical form factor. Bending a belt causes non-uniform internal stresses within the belt that can cause accelerated degradation. Thus, minimizing the amount of bend in the belt increases maximum load capacity and service life. To minimize the amount of bend, the device can include relatively large sheaves, and can include only bends in a single direction, that is, avoiding "back bending" or contra-flexion of the belt. The disclosed pulley configuration is designed to allow for large sheaves contained within a relatively small cross-section and does not contra-flex the belt.

[0014] The details of one or more implementations of the subject matter of this specification are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages of the subject matter will become apparent from the description, the drawings, and the claims.

Description

DESCRIPTION OF DRAWINGS

[0015] To describe technical solutions in the implementations of the present specification or in the existing technology more clearly, the following briefly describes the accompanying drawings needed for describing the implementations or the existing technology. The accompanying drawings in the following descriptions merely show some implementations of the present specification, and a person of ordinary skill in the art can still derive other drawings from these accompanying drawings without creative efforts.

[0016] FIG. **1** depicts an example single action, belt-driven, expanding force linear actuator.

[0017] FIG. **2** illustrates motion of traveling sheaves in the expanding force linear actuator of FIG. **1**.

[0018] FIG. **3** depicts an example belt topography for the belt driven, expanding force linear actuator of FIG. **1**.

[0019] FIG. **4** depicts a perspective view of some internal components of the expanding force linear actuator of FIG. **1**.

[0020] FIG. **5** depicts an end view of traveling sheaves for the belt-driven linear actuator of FIG. **1**.

[0021] FIG. **6** is a partial cut-away diagram illustrating span geometry within the belt-driven linear actuator of FIG. **1**.

[0022] FIG. **7** illustrates a partial cut-away diagram illustrating fixed sheaves within the belt-driven linear actuator of FIG. **1**.

[0023] FIG. **8** illustrates a partial cut-away diagram illustrating fixed sheaves of the linear actuator of FIG. **1** with some sheaves removed to show bearing structure.

[0024] FIG. **9** illustrates a partial cut-away diagram showing a set of fixed sheaves on a shared axle of the linear actuator of FIG. **1**.

[0025] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0026] This disclosure describes a pulley system which can be used to enable contraction and

extension of a belt-driven linear actuator under compression loading.

[0027] FIG. **1** depicts an example single action, belt-driven, expanding force linear actuator **100**. The linear actuator **100** includes a cylinder **102**, and a drive system **104** that operates the cylinder **102**. The cylinder **102** includes a casing **112**, an output shaft **110**, a fixed sheave block **114** and other components which house and make up an internal pulley system that operate to extend the output shaft **110** to the right in the illustrated figure. As shown, the cylinder **102** is in a contracted state. When the drive system **102** removes belt from the cylinder **102**, the output shaft **110** will protrude, translating right (as illustrated) and expanding the linear actuator **100**. When the drive system **102** pays out belt to the cylinder **102**, the output shaft **110** will translate to the left (as illustrated), contracting the linear actuator **100**. The drive system **104** includes a motor **116**, a capstan **118**, a stowage reel **106**, and redirection sheaves **108**.

[0028] The drive system **104** works to withdraw the belt **110** from the cylinder **102** by using the motor **116** to rotate the capstan **118**. The motor **116** can be an electric motor, such as a brushless DC motor (e.g., Teknic Hudson or Parker GVM), a stepper motor, an AC motor, or another type of electric motor. Because the pulley system within the cylinder **102** includes a high reduction (e.g., 5:1 or 10:1), a relatively small motor can generate a large amount of force at the output shaft **110**. The motor **116** rotates the capstan **118**, which is frictionally engaged with the belt **120**, as the belt **120** is wrapped around the capstan **118** by one or more turns. A stowage reel **106** or spool is provided to take in excess belt **120** as it is removed from the cylinder **102** and maintain tension as belt **120** is payed out into the cylinder **102**. The drive system **104** can be similar to the drive system disclosed in U.S. Pat. No. 11,746,860 the contents of which are hereby incorporated herein in their entirety.

[0029] While the linear actuator **100** has been illustrated as including the stowage reel **106**, in some implementations, the system includes no stowage reel. In such cases, for example, a set of opposed block and tackle pulley systems within cylinder **102** can exchange belt between them so the total length of belt within the cylinder **102** does not substantially change as the actuator translates.

[0030] The cylinder **102** houses the pulley system of the linear actuator **100**. It includes the casing **112**, which can provide structural support as well as sealing and foreign body protection for the internals. A fixed sheave block **114** can be mounted at one end of the casing **112**, which contains bearings and axles for a number of fixed sheaves, which are discussed in more detail below with respect to FIGS. **2-9**. While called a "cylinder" and generally cylindrical in shape, it should be noted that the cylinder **102** need not be cylindrical. In some implementations the cylinder **102** is a rectangular shape, or triangular, or any suitable shape for housing the internal components for the linear actuator **100**. Casing **112** can be made of steel, aluminum, composite materials, polyurethane, or other suitable structural material.

[0031] In some implementations, the cylinder **102** is hermetically sealed, providing a closed interior volume, and protecting the internals from particulate or gaseous contamination. In some implementations, the internal volume of the cylinder **102** can be pressurized, or at a vacuum relative to ambient pressure. In some implementations, the cylinder **102** includes an emergency pressurization system, which can provide static hold capability or energy absorption in the event of a belt failure. For example, if the device is carrying a load, and the belt fails, the cylinder **102** can be rapidly pressurized to operate, at least temporarily, as a pneumatic cylinder, in order to prevent or stop inadvertent movement of the linear actuator **100** due to the load.

[0032] The output shaft **110** can be a solid shaft that extends through one end of the fixed sheave block **114**. Solid shafts can be advantageous in that they are stronger than a hollow shaft for a given weight or diameter. In some implementations, the output shaft **110** is hollow, which allows for reduced weight or increased stiffness at a given weight of the output shaft **110**.

[0033] It should be noted that the drive system **104** is illustrated throughout this disclosure as mounted directly adjacent to, and oriented in parallel, with the cylinder **102**. However, the drive system **104** can be remote from the cylinder and mounted at various orientations or distances

depending on the particular application for the linear actuator **100**. Similarly, while stowage reel **106** is shown adjacent to the drive system **104** and the cylinder **102**, it can be remote, or separate from both as well.

[0034] FIG. **2** illustrates motion of traveling components in the expanding force linear actuator **100**. The casing **112** has been removed giving a view of internal components of the cylinder **102**, including certain spans of the belt **120** and the traveling sheave group **204**. Further, the cylinder **102** has been reproduced with the linear actuator **100** in three different positions of travel: contracted, middle, and extended. Finally, the fixed sheave block **114** has been removed, revealing the fixed sheave group **202**.

[0035] As the drive system **104** draws belt **120** from the cylinder **102**, the spans between the fixed sheave group **202** and the traveling sheave group **204** become shorter. The traveling sheave group **204**, which are affixed to an end of the output shaft **110**, are pulled toward the fixed sheave group **202**, and the output shaft **110** translates in the direction of motion **206**, extending (or expanding) the linear actuator **100**.

[0036] The belt **120** can be a flat belt that is formed by encasing two or more wire ropes in a jacket. For example, ten multi-strand wire ropes can be aligned in a parallel manner and then enclosed in a polyurethane jacket. The wire ropes can be enclosed by over molding using injection molding, or the jacket material can be extruded over the wire ropes. In general, the belt **120** is a flexible belt capable of withstanding large tensile loads. This can enable a high strength and high durability belt that can withstand sufficient bend stresses to allow for the use of relatively small diameter sheaves. In some implementations, the wire ropes within the belt **120** can be pre-tensioned in a non-uniform manner to increase the twist and fleet angle tolerance of the belt **120**.

[0037] While illustrated throughout this disclosure as having a rectangular cross section, the belt **120** can have a square, trapezoidal, or triangular cross section. In some implementations, the cross section of the belt changes. For example, a rectangular belt can be used in the drive system, but a trapezoidal belt can be used in portions of the cylinder section.

[0038] FIG. **3** depicts an example belt topology **300** for the belt driven, expanding force linear actuator **100** of FIG. **1**. The belt **120** can be viewed in sections: a drive section **302**, a traveling sheave section **304**, a fixed sheave section **306**, and a shock absorption section **308**, and an anchor section **310**

[0039] The drive section **302** of the belt **120** includes a number of turns around the capstan **118** (shown in FIG. **1**), and in some implementations, an idler shaft, before the belt passes into the cylinder **102**. Additionally, a pair of bends are caused by the redirection sheaves **108** (shown in FIG. **1**), which can be used to position the drive system **104** and stowage reel **106** at the desired location relative to the cylinder **102**. While three turns around the capstan **118** are illustrated, fewer or greater turns can be used in the drive section **302**.

[0040] The traveling sheave section **304** is the portion of the belt **120** that passes over the traveling sheave group **204**, forming multiple spans between the traveling sheave group **204** and the fixed sheave group **202** that result in a reduction. The illustrated belt topology **300** includes ten spans between the fixed sheaves and the traveling sheaves and will result in a 10:1 reduction ratio between the drive section **302** and movement of the traveling sheave section **304**. That is, for every ten inches of belt drawn from the cylinder **102**, the traveling sheave section **304** and output shaft **110** will translate one inch, neglecting second order effects such as material elasticity and manufactured component tolerance.

[0041] The fixed sheave section **306** is the portion of the belt **120** routed over the fixed sheave group **202** which is rigidly mounted to the fixed sheave mounting block **114**. Together, these components provide the reaction force to "pull" the traveling sheave group **204** and output shaft **110** during an expansion movement.

[0042] As the belt **120** exits the final fixed sheave **202**, it passes into a shock absorption section **308**. In the shock absorption section **308** the belt passes over a shock absorber **402** (described

below with reference to FIG. **4**) and terminates at an anchor **410**. The anchor **410** is a wedge mechanism that affixes the belt **120** to the structure of the device, providing a fixed reference for the remainder of the belt **120**. In some implementations, an additional anchor is provided within the stowage reel **106**.

[0043] It should be noted that throughout the traveling sheave section **304**, the fixed sheave section **306**, and the shock absorption section **308**, the belt is bent in a single direction, or towards a single side. There is no back bending or contra-flexion in the belt with this belt topology, which enables an increased working load. This is because the wire ropes within the belt experience less cyclic bending stress, and thus can withstand higher tensile loads while controlling for fatigue life.

[0044] FIG. **4** depicts a perspective view of some internal components of the expanding linear actuator **100**. The traveling sheave group **204** is mounted to the end of the output shaft **110**. The fixed sheave group **202** is mounted to the fixed sheave block **114** (shown in FIG. **1**) and the belt **120** is reeved around the fixed sheave group **202** and traveling sheave group **204** to form a number of spans, before passing over the shock absorber **402** and terminating at the anchor **410**.

[0045] The shock absorber **402** can be a gas or hydraulic spring/damper system that provides the linear actuator with some measure of compliance for the purpose of shock tolerance. For example, rapid increases in loading on the linear actuator **100** can result in large tension impulses in the belt. The shock absorber **402** can compress, relieving that tension and damping the energy from the impulse. In some implementations, the shock absorber **402** is a nitrogen charged gas spring, such as a Tevema H4200 series.

[0046] Several cutaway marks are indicated in FIG. **4**, which show where the view for FIGS. **6**, **7**, **8**, and **9** are illustrated.

[0047] FIG. **5** depicts an end view of the traveling sheave group **204** for the belt-driven linear actuator **100**. Certain structural components have been removed for clarity, and the formation of the traveling sheave group **204** is shown.

[0048] The traveling sheave group **204** generally include two pairs of two sheaves, with an intermediate sheave providing a transition between them. Specifically, traveling sheave **1 504**A and traveling sheave **2 504**B form a first pair. The belt **120** passes over one of the fixed sheave group **202**, then around traveling sheave **1 504**A, back to the fixed sheave group **202**, then around traveling sheave **2 504**B, then follows a twisted span back to the fixed sheave group **202**. The belt **120** returns to traveling sheave **3 504**C, passes over it and then back to the fixed sheave group **202**. Another twisted span feeds from the fixed sheave group **202** over traveling sheave **4 504**D, then back to the fixed sheave group **202** before passing around traveling sheave **504**E, around the final fixed sheave, through the shock absorber section **308**, and to anchor **410**.

[0049] It should be noted that the twisted spans will have dynamic twist ratios, with their twist ratio increasing as the traveling sheave group **204** translate toward the fixed sheave group **202**. Twist ratio for a span of belt can be defined as the length of a free span divided by the belt width for a 90-degree twist. For example, a belt with a 10 mm width and a 300 mm free span that is twisted at 45 degrees would have a twist ratio of 60:1. The twist ratio can be given by the equation

[00001] $T.R. = \frac{L_{\text{Span}}}{W_{\text{belt}}} \times \frac{90}{\text{Twist}}$,

where L.sub.span is the length of the free span, W.sub.belt is the width of the belt, and Twist is the amount of twist in the span in degrees. In some implementations, twist ratios of 20:1 or less result in a reduction in service life of the belt. In some implementations, higher twist ratios (e.g., 12:1, or 15:1, etc.) can be permissible if a compensating fleet angle is introduced. This is further described in U.S. Pat. No. 11,835,132 the contents of which are incorporated herein by reference.

[0050] In the illustrated implementation, where the sheaves form an approximately triangular shape, the twisted spans in the linear actuator **100** have twists of approximately 60-75 degrees each, including the belt in span **506** that connects the fixed sheaves **202** to the drive system **104**, the span entering traveling sheave **2 504**B, and the span entering traveling sheave **3 504**C. The configuration of traveling sheaves illustrated in FIG. **5** represents a tradeoff between maximizing sheave size, and

thus load bearing capability of the belt, and number of sheaves, and thus reduction ratio. Including more sheaves to increase the reduction ratio requires smaller sheaves to fit within the same footprint, and therefore would decrease the load capacity of the belt bending around each sheave. Further, to prevent contra-flexion within the belt, more twisted spans with larger twists (a greater twist ratio) would be required.

[0051] FIG. **6** is a partial cut-away diagram illustrating span geometry within the belt-driven linear actuator **100**. Spans **602**A-J act in tension to pull the traveling sheave group **204** toward the fixed sheave group **202** during an expansion movement and thereby translate the output shaft **110** along its centerline **604**.

[0052] One feature of the illustrated configuration is that the center of action, or the geometric average of all the tensile forces applied to the group of traveling sheaves is nearly coincident with the shaft centerline **604**. This geometry is advantageous in that the net force applied to the output shaft **110** is nearly entirely in the direction of travel, thus reducing (e.g., minimizing) undesirable moments and additional friction due to off-axis forces. In some implementations, the center of action is less than 2 mm for a cylinder **102** with a 305 mm inner diameter. In some implementations, this is considered approximately coincident with the shaft centerline **604**. Approximately coincident in this context can be defined to be a geometric center of loading action by the belt system that deviates from the output shaft centerline **604** by less than 10 percent of the overall cylinder **102** diameter.

[0053] FIG. **7** illustrates a partial cut-away diagram illustrating the fixed sheave group **202** within the belt-driven linear actuator **100**. The belt **120** enters the fixed sheave group **202** from the drive system **104** via the belt in span **506**, and passes around fixed sheave **1 702**A, before traveling to the traveling sheave group **204**, then returning to pass around fixed sheave **2 702**B. The belt **120** passes from fixed sheave **2 702**B to the traveling sheave group **204** and returns to fixed sheave **3 702**C. This continues as the belt passes between the traveling sheaves and fixed sheaves **4**, **5**, and **6 702**D-F, before passing down the belt out span **706** to the anchor section **310**. The fixed sheave group **202** is mounted to the fixed sheave block **114** by three bearing assemblies **704**. Each bearing assembly **704** supports two fixed sheaves and enables each fixed sheave to rotate independently. The bearing assemblies **704** are arranged approximately 120 degrees apart around the output shaft **110** and the fixed sheave group **202** forms a set of two triangles to maximize their size within the given space. Additionally, fixed sheave **1 702**A and fixed sheave **6 702**F are larger than their paired inner fixed sheaves **702**B, **702**E, respectively. This permits the belt in span **506** and belt out span **706** to travel externally to the main cylindrical volume formed by the casing **112**, while fixed sheave **4 702**D has a smaller diameter than fixed sheave **3 702**C. This configuration maximizes sheave size within the footprint of the cylinder, while enabling alignment of spans to the traveling sheave group **204** with minimal fleet angles and twist.

[0054] The fixed sheave group **202** generally forms a ring or annulus (in this case triangular arrangement) around the output shaft **110**. In order to maximize the use of the space, the sheaves are positioned as close to the output shaft **110** as possible without contacting the output shaft. In some implementations, there is less than 1 mm of space between the inner fixed sheave and the output shaft.

[0055] FIG. **8** illustrates a partial cut-away diagram illustrating fixed sheaves with some sheaves removed to show bearing structure. The bearing assemblies **704** retain the sheaves on their respective axles using a flanged retention disk **802** and a retaining bolt **804** that passes through the center of the axle (shown below with respect to FIG. **9**). Thrust bearings **806** are provided between the outer sheaves and the fixed sheave block **114**, as well as between individual sheaves. The flanged retention disk **802** compresses the sheave stack as retaining bolt **804** is threaded into a retaining cap (shown below in FIG. **9**) on the fixed sheave block **114**. The flanged retention disk **802** can sit within a recess in the inner flange, and thus the assembly does not protrude inward past the inner edge of the flange.

[0056] FIG. **9** illustrates a partial cut-away diagram showing a set of fixed sheaves on a shared axle. The axle **902** can be rigidly affixed to the fixed sheave block **114**. Sheaves (e.g., fixed sheaves **1** and **2**, **702**A-B) can be fitted around the axle **902** and rotate on bearings **904** independently of the axle **902**. The flanged retention disk **802**, retaining bolt **804** and retention cover **912** can work to axially compress the sheaves and bearings onto the fixed sheave block **114**. Thrust bearings **806** provided between sheaves reduce friction and enable independent rotation. An additional bearing **910** is provided to support retention cover **912** and allow it to rotate independently of the axle **902**. In the illustrated example, the inner sheave (fixed sheave **2 702**B), flanged retention disk **802**, retaining bolt **804**, and retention cover **912** will rotate as a single unit. The axle **902** remains fixed, and fixed sheave **1 702**A will rotate independently from the other components. The other fixed sheave groups with their respective bearing assemblies **704** can contain identical bearing components and utilize the same methods of assembly and component loading and function.

[0057] To help a person skilled in the art better understand the technical solutions in the present specification, the following clearly and comprehensively describes the technical solutions in the implementations of the present specification with reference to the accompanying drawings in the implementations of the present specification. Apparently, the described implementations are merely some rather than all of the implementations of the present specification. All other implementations obtained by a person of ordinary skill in the art based on one or more implementations of the present specification without creative efforts shall fall within the protection scope of the implementations of the present specification.

[0058] The foregoing description is provided in the context of one or more particular implementations. Various modifications, alterations, and permutations of the disclosed implementations can be made without departing from scope of the disclosure. Thus, the present disclosure is not intended to be limited only to the described or illustrated implementations, but is to be accorded the widest scope consistent with the principles and features disclosed herein.

Claims

1-20. (canceled)

21. A pulley system comprising: a plurality of fixed sheaves arranged to at least partially encircle an output shaft; a plurality of traveling sheaves coupled to the output shaft, the output shaft configured to pass through the fixed sheaves and translate along an axis of travel, wherein the plurality of traveling sheaves are arranged such that a geometric average of belt tension created by spans of belt between the plurality of traveling sheaves and the plurality of fixed sheaves is located within the output shaft; and a belt extending between and around the plurality of fixed sheaves and the plurality of traveling sheaves.

22. The system of claim 21, wherein the plurality of fixed sheaves comprises six sheaves arranged in pairs on three axles that are mounted to a device casing, wherein one pair of sheaves is arranged such that the sheave positioned farther from the output shaft is smaller in diameter than the sheave positioned closer to the output shaft, and wherein two pairs of sheaves are arranged such that the sheaves positioned farther from the output shaft are larger in diameter than the sheaves positioned closer to the output shaft.

23. The system of claim 22, wherein the plurality of fixed sheaves are retained on the three axles by a set of flanged end caps that are each bolted to the device casing through a center of their respective axle.

24. The system of claim 22, wherein two belt spans each exiting the larger of the sheaves on the two pairs of sheaves arranged such that the larger diameter sheave positioned farther from the output shaft are positioned externally to a casing that encompasses belt spans between the fixed sheaves and the traveling sheaves.

25. The system of claim 21, wherein the plurality of traveling sheaves comprises five sheaves

coupled to an end of the output shaft.

26. The system of claim 21, wherein the belt forms at least ten spans between the plurality of traveling sheaves and the plurality of fixed sheaves.

27. The system of claim 21, wherein the device casing at least partially encloses the pulley system, and wherein a device casing is cylindrical.

28. A belt driven linear actuator comprising: a support structure; an output shaft; a pulley system comprising: a plurality of fixed sheaves arranged to at least partially encircle the output shaft; a plurality of traveling sheaves coupled to the output shaft, the output shaft configured to pass through fixed sheaves and translate along an axis of travel, wherein the plurality of traveling sheaves are arranged such that a geometric average of belt tension created by spans of belt between the plurality of traveling sheaves and the plurality of fixed sheaves is located within the output shaft; and a belt extending between and around the plurality of fixed sheaves; and a belt drive mechanism configured to withdraw belt from the pulley system and pay out belt to the pulley system.

29. The actuator of claim 28, wherein the plurality of fixed sheaves comprises six sheaves arranged in pairs on three axles, and wherein the three axles are mounted to the support structure, wherein one pair of sheaves is arranged such that the sheave positioned farther from the output shaft is smaller in diameter than the sheave positioned closer to the output shaft, and wherein two pairs of sheaves are arranged such that the sheaves positioned farther from the output shaft are larger in diameter than the sheaves positioned closer to the output shaft.

30. The actuator of claim 29, wherein the plurality of fixed sheaves are retained on the three axles by a set of flanged end caps that are each bolted to the support structure through a center of their respective axle.

31. The actuator of claim 29, wherein the belt drive mechanism comprises an electric motor and a capstan.

32. The actuator of claim 28, wherein the plurality of traveling sheaves comprises five sheaves coupled to an end of the output shaft.

33. The actuator of claim 28, wherein the belt forms at least ten spans between the plurality of traveling sheaves and the plurality of fixed sheaves.

34. The actuator of claim 28, wherein the pulley system is at least partially enclosed by a cylindrical casing.

35. A method of operating a linear actuator, the method comprising: removing a portion of belt from a pulley system using a belt drive mechanism, wherein the pulley system comprises: a plurality of fixed sheaves arranged in to at least partially encircle an output shaft; a plurality of traveling sheaves coupled to an output shaft, the output shaft configured to pass through the fixed sheaves and translate along an axis of travel, wherein the plurality of traveling sheaves are arranged such that a geometric average of belt tension created by spans of belt between the plurality of traveling sheaves and the plurality of fixed sheaves is located within the output shaft; and the belt extending between and around the plurality of fixed sheaves and the plurality of traveling sheaves.

36. The method of claim 35, wherein removing the portion of the belt from the pulley system causes the plurality of traveling sheaves and the output shaft to translate along the axis of travel in an expanding direction.

37. The method of claim 35, comprising: paying out a portion of the belt to the pulley system to enable the output shaft to translate along the axis of travel in a contracting direction.

38. The method of claim 35, wherein the plurality of traveling sheaves comprises five sheaves coupled to an end of the output shaft.

39. The method of claim 35, wherein the belt drive mechanism comprises a capstan, and wherein the belt extends from a first anchor point, through the pulley system, about the capstan, and to a stowage reel.

40. The method of claim 39, wherein the capstan is operated by an electric motor.