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LEVER-OPERATED ADJUSTMENT DEVICES, FIT SYSTEMS, AND LINE TENSIONING SYSTEMS

Abstract

An adjustment device includes a housing supporting a rotatable spool that is operably coupled to a tension line. The spool is configured to rotate about a first axis in a first direction to wind the tension line around the spool and is configured to rotate about the first axis in a second direction opposite the first rotational direction to unwind the at least one tension line from the spool. The device includes a lever pivotally coupled to the housing and configured to rotate about a second axis. The lever is selectively coupled to the spool to drive rotation of the spool in the first direction. The device also includes a release mechanism that is configured to selectively release the spool such that the spool is free to rotate in either the first or second direction in response to manual forces applied to the release mechanism.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. Ser. No. 17/615,772, filed Dec. 1, 2021, which is a 35 USC § 371 Application of PCT/US2020/036324, filed Jun. 5, 2020, which claims priority to U.S. Provisional Application 62/857,320 filed Jun. 5, 2019, and to U.S. Provisional Application 62/937,808 filed Nov. 20, 2019, the entire contents of which are hereby incorporated herein in their entireties.

BACKGROUND
1. Field
[0002] The present disclosure relates to low profile adjustment devices for use with various articles, fit system, and line tensioning systems.
2. State of the Art
[0003] How well a wearable article or device fits the body is highly important in the daily function of humans or even for animals. For example, wearable articles and devices can include, by way of example, garments, shoes, backpacks, sporting gear, wearable protective devices, sporting braces, orthosis, and/or prosthesis. Several factors can be weighed in how appropriate or satisfactory a wearable article or device fits the body, including whether the fit system transmits satisfactory load, provides satisfactory stability, suspends on the body, provides efficient congruency of the article or device during motion, provides sufficient mobility, is easily fitted, and/or is comfortable. These factors can be considered determinates in how appropriate or effective the fit of the article or device is on the body and they are directly related to how the article or device is secured or fastened to the body. Generally, the wearable articles or devices are secured to the body by tightening around the body. The mechanisms and associated methods of how articles or devices are secured to the body are hereby referred to as fit systems.
[0004] Fit systems and related devices and methods generally are operably attached to one or more flexible elongate members or tension lines (such as straps, cables, laces, etc.) with one or more attachment points or interfaces to the article or device. The attachment points or interfaces may decrease in distance relative to one another or relative to the fit system, which can be referred to as contraction or shortening. Such contraction can involve decreasing the effective length of the flexible elongate member(s) of the fit system and possibly increasing the amount of tension (or tensile loading) experienced by the flexible elongate member(s) of the fit system. Such contraction can occur when tightening or closing or other movement of the article or device with respect to the body. Alternatively, the attachment points or interfaces may increase in distance relative to one another or relative to the fit system, which can be referred to as extension or lengthening. Such extension can involve increasing the effective length of the flexible elongate member(s) of the fit system and possibly deceasing the amount of tension (or tensile loading) experienced by the flexible elongate member(s) of the fit system. Such extension can occur when loosening or other movement of the article or device with respect to the body.

[0005] The determinates of the appropriateness and effectiveness of a fit system may be associated with design elements of the fit system including: the mechanisms and associated methods for contraction and extension, the inherent mechanical advantage of a given fit system, mechanical reliability of the overall system and toughness of individual components, maximum load and tension, distance between the attachment points or interfaces in the maximum contracted and maximum extended positions, profile height of the fit system, width and length of the fit system, rigidity of the fit system and its components, whether the contraction and extension is incremental or analog in nature, how smooth or abrupt is the contraction and extension, attachment requirements of the fit system, system weight and suspension forces provided by the fit system, and pressure distribution of the fit system.

[0006] The mechanism/s and associated methods of use weigh heavily on the user experience of the fit system and is the driving factor for many of the other determinates of the fit system. For example, a mechanism may be mechanically effective but may have poor ergonomics. The mechanism may also affect the speed and direction of the contraction and extension. For example, the gear ratio mechanism within a fit system may provide high mechanical advantage, but a slow speed of contraction, which may be ideal for some applications and too slow for others. In another applications, the speeds of contraction and extension may be key for some applications. For example, certain military applications such as a fit system for a military aid pack or backpack may need to have a high speed of contraction and very high speed of extension such that the operator can quickly remove the pack if they need to quickly become mobile to avoid harm. In this application, a high mechanical advantage for contraction or extension may be less important because most users would have a relatively high level of strength. In still other applications, the direction of pull of the contraction or extension may be important. For example, contracting in a single direction could cause misalignment of a knee joint in an orthosis as the user tightens the brace onto their body. In these cases, a balanced, dual direction fit system would be more appropriate. How easily a fit system performs contraction and extension is paramount in its ability to deliver optimal fit and user experience. Many users of orthopedic devices have compromised strength and/or dexterity so mechanisms and methods that make the fit system easy for them to contract to the desired amount and easily extend for release is a huge need and large benefit. Conversely, if a fit system is so easily engaged for contraction or extension that it is accidentally triggered, that can be a serious functional problem as well. Mechanism and methods drive other factors such as the inherent mechanical advantage of the system and the increments of tightening. Some applications may require small increments of contraction or extension whereas others may be optimized by larger and therefore faster increments of change.

[0007] In addition, some mechanisms and methods of fit systems may allow for an opening or separation between attachment points or interfaces whereas others may be better suited or even require the fit system to remain as a single unit between attachment points or interfaces. Some applications may require that a fit system opens up in order to don and doff the device while others may not. For example, a leg brace may require that users open up the device in order to place their leg into the device whereas protective pants for motorcycle riders may allow for a waist fit system stay in one piece and loosen only while they pull it up to their waist.

[0008] The inherent mechanical advantage of a fit system is a byproduct of the mechanisms and the methods associated with the fit system. Such fit system can provide a quantifiable mechanical advantage ratio which is the amount of output force over the amount of input force. The speed or time needed to contract or extend the fit system a given distance is usually inversely correlated with mechanical advantage such that when mechanical advantage is high, speed is low and vice versa. Many applications differ in the mechanical advantage requirement, but most applications have a specific ratio or range of ratios that is optimal for function. If the mechanical advantage is too high or more than required for a given application, it may unnecessarily sacrifice speed. Mechanical advantage within a fit system directly relates to the maximum tension and load of the system. The maximum tension and load of a fit system is described in detail below.

[0009] The mechanical reliability and toughness of the fit system relates to the materials utilized by parts therein, geometry, dimensions, and manufacturing methods. Specifically, the overall fit system may only be as strong as its weakest link. Some parts can fail and cause catastrophic failure while others may not. Failure of some fit systems could lead to the users getting trapped or stuck in their device or with their device. In other situations, the user may be highly dependent on the device. Failure of a fit system could potentially even contribute to a fatal accident. Reliability is therefore extremely important especially in certain circumstances and applications.

[0010] Maximum tension of a fit system is typically dependent on the maximum tensile loading of the flexible elongate member(s) of the fit system. In many applications, the maximum tensile loading relates directly to the maximum input force multiplied by the mechanical advantage. The input force is most often the manual force of the user but may be the force imposed by another person or an electronic or other automated system. The input force is transferred to the fit system members via the mechanisms within the fit system which may or may not include mechanical advantage. The tensile loading of the flexible elongate member(s) of the fit system can transfer load or force onto the user's body. Generally, the load is directed into the body or, in other words, towards the center of the body's long axis or the long axis of a limb but may also be slightly oblique to the direction directly towards the long axis. If such loading forces are directed in an angle that is too oblique to the long axis they will likely cause the device to shift proximally or distally on the body unless counterbalanced by a geometric feature of the body or other feature. The amount of load transferred onto the body can also related to other factors. For example, the amount of body exposure from the device seen by the fit system will affect the how much of the tension force is transferred directly onto the body or into the device.

[0011] The loading directed into the body can apply pressure to the body. Generally, the pressure distribution applied to the body is dependent on the amount of loading applied by the fit system to the body divided by the surface area of the applied loading. Pressure distribution of the fit system is explained in further detail below. In many cases, the fit system can transfer some tension forces onto the device (for example, by the device changing shape or reducing in volume), thereby reducing load applied to the body. The amount of desired load or optimal load delivered onto the body by the fit system may differ per application, as the body changes, during activity changes, within certain movements, in certain positions, and/or over time. Although the optimal loads may vary per application and other variables, optimal performance is generally seen within a definitive range. The humans and animals generally prefer a similar range of load and associated pressure onto the body and within specific segments of the body. Beyond the level of preference, loads and pressures that are beyond a recommended range may cause a reduction in blood flow and/or other damage, discomfort, or pain. Conversely, if loads and pressures are too low, the device may fall down on the body or be loose on the body which may lead to damage, discomfort, or pain.

[0012] The maximum effective length of the flexible elongate members of the fit system can be referred to as the travel within a fit system. Travel within a fit system may relate to the amount of space available for a flexible elongate member to collect into the fit system or the distance of linear teeth in a ratchet ladder. The available amount of travel within a fit system may limit the amount of load that a fit system can deliver onto the body in that the maximum travel may be reached before the user gets to their desired amount of load onto the body. Travel may also directly affect device sizing in that a fit system with greater travel is likely to accommodate a wider range of body sizes and vice versa. These factors might suggest that fit systems should always include a maximum or large amount of travel. However, while increased travel may be beneficial, it often has a negative or inverse correlation on other determinates of the fit system such as the size, profile, weight, and other factors discussed below.

[0013] The profile height of the fit system is extremely important to product developers and end users. Profile height refers to the distance that the fit system protrudes away from the body or, in other words, how much it sticks out. Developers and end users have a strong preference or requirement for the fit system to have a low-profile for the aesthetic look and finish quality that they demand. Moreover, the profile height also plays a role in function and safety. If a fit system has a large profile height it will have a higher risk of catching on things or it may make it difficult or impossible to wear clothing over the fit system. Beyond these undesirable attributes, a fit system with a large profile can be a significant risk of injury due to the fact that if the user falls or bumps into something, the bulk of the fit system can be pushed into the body and can cause injury.

[0014] Similar to the profile height, the width and length of a fit system may also be important for applications of use. Width or length can limit applicability in some cases that may have a limited surface area of application. For example, shoes have a limited surface area that is acceptable for a fit system. Fit systems may be limited in their applicability to shoes if their width or length is over 45 mm or even 35 mm in some cases. However, beyond surface area limitations, larger width and length are far more acceptable for most applications fitting the body as compared to profile height.

[0015] In some cases, fit requirements can be very specific and a distance of one millimeter can be the difference in too loose and just right. In these cases, an analog fit system that can adjust in a continuous and controlled manor may be ideal. In other applications, incremental tightening provides the appropriate amount of fidelity while enabling for a wider array of fit system mechanisms. Incremental systems are often faster than analog systems that provide a control at a micro level. All incremental systems are not created equal. Some incremental fit system may offer small increments like 1.5 millimeters whereas others may offer large steps of 6 millimeters. Requirements for the distance between increments are specific per application but in general the range is between 0.5 mm and 8 mm. Regardless of whether a system is incremental or analog, the mechanism or method of use may provide a smooth transition as it is used to adjust fit or it may provide an abrupt experience. In general, the experience is understandably more favorable if it is more controlled and smoother. However, some cases require fast release or removal of a device.

[0016] Various fit systems have been proposed. An example of one such device is described in U.S. Pat. No. 9,867,430 (Boa Technologies). This prior art stacks fit system mechanisms and members vertically and thereby has a large profile height. The profile of commercial embodiments of this technology are relatively high in order to provide their respective mechanical advantage. Moreover, such profile heights for this technology are excessive for many applications. This commercial technology is also limited in mechanical reliability. The system utilizes cables or laces that are approximately 0.8 mm to 1.0 mm thick and can fail during use of many applications. Additionally, release is abrupt and may be shocking and jarring to the user. Moreover, users with poor hand dexterity lack the capacity to wind or release the tension line of the fit system.

[0017] Ratchet ladders have sufficient mechanical advantage for many applications, but the ladder strap teeth often cannot accommodate angles greater than 30 degrees without skipping. Additionally, release is abrupt and may be shocking and jarring to the user. Also, these systems are generally between 25 mm and 45 mm and are thereby excessively bulky in profile for many applications.

[0018] Ratchet straps offer large mechanical advantage and high mechanical reliability, however their profile height, difficulty and abruptness in releasing mechanisms, and challenge of donning wherein one needs to feed a strap through a split axis and hold the strap in tension in order to start it: all make for these systems to be inapplicable as a fit system.

[0019] Over-center cam buckles serve as fit systems for ski boots and other similar products. These fit systems and other similar products effectively provide mechanical advantage when they are attached to rigid plastic structures on both sides but they do not include fastening mechanism that allow them to mount to a strap and the base of the over-center cam would create high peak pressures if it were used on a loose strap due to its small base of support. The catch mechanisms for these devices are also not designed to work with a loose strap and create difficult ergonomics if they are used with loose straps. Moreover, these systems offer no security latch mechanisms to maintain the strap in the closed position, do not offer macro tightening and loosening, and are highly dependent on the specific geometry (angles and contours) of the application. All of these factors amount to over-center systems not being applicable to products fitting the body with the exception of products that include hard plastic rigid shells like ski boots.

[0020] Webbing straps with hook and loop fasteners (sold under the tradename VELCRO) is often used as a fit system in almost all devices that fit the body ranging from shoes to neck braces. The ubiquitous use of hook and loop systems may relate to its low cost, accessibility, low-profile, and ease in integration into product development; all fit system factors that affect a company's motivation to integrate a fit system into their product beyond the end user attributes discussed in detail above. Buckles, fasteners, and chafes are often utilized in combination with hook and loop fasteners in order to add some mechanical advantage and/or provide greater ease of use. Although hook and loop fasteners are widely used, end users often complain of the noise it makes during removal, how it often attaches to unintended materials and surfaces, how it collects lint, how it is difficult to tighten and loosen especially for those with low strength capacity, and how it tends to wear out with prolonged cycle use.

[0021] The most common fit system utilized for shoes is traditional laces. Laces offer minimal mechanical advantage but that is all that is needed in most shoes since the dorsum of the foot offers a large surface area to suspend on. Even though the need for mechanical advantage and suspension are low, fast, and ergonomic methods to tighten and loosen shoes is still desired.

[0022] Line tensioning systems and related methods can generally include one or more flexible elongate members (such as straps, cables, wires, etc.) with one or more attachment points or interfaces to an article, device, or structure. Similar to fit systems, the attachment points or interfaces may decrease in distance relative to one another or relative to the line tensioning system, which can be referred to as contraction or shortening. Such contraction can involve decreasing the effective length of the flexible elongate member(s) of the line tensioning system and possibly increasing the amount of tension (or tensile loading) experienced by the flexible elongate member(s) of the line tensioning system. Alternatively, the attachment points or interfaces may increase in distance relative to one another or relative to the line tensioning system, which can be referred to as extension or lengthening. Such extension can involve increasing the effective length of the flexible elongate member(s) of the line tensioning system and possibly deceasing the amount of tension (or tensile loading) experienced by the flexible elongate member(s) of the line tensioning system.

[0023] The determinates of the appropriateness and effectiveness of a line tensioning system may be associated with design elements of the line tensioning system including: the mechanisms and associated methods for contraction and extension, the inherent mechanical advantage of a given line tensioning system, mechanical reliability of the overall system and toughness of individual components, maximum load and tension, distance between the attachment points or interfaces in the maximum contracted and maximum extended positions, profile height of the line tensioning system, width and length of the line tensioning system, rigidity of the line tensioning system and its components, whether the contraction and extension is incremental or analog in nature, how smooth or abrupt is the contraction and extension, attachment requirements of the line tensioning system, system weight and suspension forces provided by the line tensioning system, and pressure distribution and loading provided by the line tensioning system.

SUMMARY

[0024] Lever-operated adjustment devices (such as for fit systems and line tensioning systems) are described herein that may be useful in a variety of applications, including for wearable articles and devices. The adjustment devices include a ratcheting lever operable to drive a spool for winding at least one flexible elongate member or tension line about the spool. The lever operated adjustment devices in accordance with this disclosure have relatively higher mechanical advantage and lower profile as compared to prior art devices. In addition, the lever-operated adjustment devices include

a single-handed release mechanism that facilitates quick removal of tension in the at least one tension line.

[0025] In accordance with a first aspect, a lever-operated adjustment device includes a housing comprising a base having a lower surface extending in a plane and a cover coupled to the base. The device also includes a spool pivotally coupled to the base of housing and surrounded by the cover. The spool is configured to rotate about a first axis in a first rotational direction to wind the at least one tension line around the spool. The spool is also configured to rotate about the first axis in a second rotational direction (opposite the first rotational direction) to unwind the at least one tension line from the spool. The winding of the at least one tension line on the spool can provide for retraction of the adjustment device as part of a fit system or line tensioning system. The unwinding of the at least one tension line from the spool can provide for extension of the adjustment device as part of a fit system or line tensioning system. The first axis can be parallel to the plane of the lower surface of the base. The lever can be pivotally coupled to the housing and configured to rotate about a second axis, where the lever is operatively configured to drive the spool in the first direction to wind the at least one tension line around the spool.

[0026] The attachment device can also include a ratcheting adjustment mechanism that includes first and second engagement members supported by the housing and the lever. The first engagement member is operably coupled between the lever and the spool and has a coupled configuration that mechanically couples the lever to the spool such that pivoting motion of the lever drives the spool in the first rotational direction and prevents the spool from rotating in the second rotational direction. Also, the first engagement member has a decoupled configuration that mechanically decouples the lever from the spool.

[0027] The second engagement member is selectively coupled to the spool. The second engagement member has a coupled configuration that permits the spool to rotate in the first rotational direction while preventing the spool from rotating in the second rotational direction. Also, the second engagement member has a decoupled configuration that that mechanically decouples the second engagement member from the spool.

[0028] The release mechanism is configured to selectively release the spool by simultaneously configuring the first and second engagement members into their respective decoupled configurations. The operation of the release mechanism can be initiated by single hand movement of a user.

[0029] In embodiments, the release mechanism is configured to release the spool in response to a manual force applied to the device in a direction perpendicular to the first axis and parallel to a direction in which the tension line extends from the housing of the device. In embodiments, the release mechanism is configured to release the spool in response to a manual force applied to the device in a direction parallel to the first axis. In embodiments, the release mechanism is configured to release the spool in response to a pair of oppositely directed forces (e.g., parallel to the first axis of the spool) applied to the device.

[0030] In embodiments, the second axis can be parallel to the first axis. The second axis may be coaxial with the first axis.

[0031] In embodiments, the lever can be configured to translate relative to the housing and the spool in a first longitudinal direction parallel to the first axis to cause simultaneous disengagement of the first and second engagement members from the spool. The release mechanism can include a biasing member between the base and the lever that is configured to bias the lever in a second longitudinal direction opposite the first longitudinal direction.

[0032] In embodiments, the spool can be configured to translate relative to the housing and the lever in the first longitudinal direction parallel to the first axis. In embodiments, the spool can include an axle extending along the first axis as well as first and second driven gears fixed to the axle and spaced apart from one another along the axle. The first engagement member can include a driving gear configured to engage the first driven gear of the spool, and the second engagement

member can include a ratchet gear configured to engage the second driven gear of the spool.
[0033] In embodiments, the first and second driven gears, the driving gear, and the ratchet gear can be side-facing gears having gear teeth extending in a direction parallel to the first axis. The driving gear, first and second driven gears, and the ratchet gear can be coaxially aligned with one another along the first axis. In embodiments, the first and second driven gears can have angled teeth with a drive side and a coast side, where the angle of the teeth of the first and second driven gears are oppositely arranged. In embodiments, the driving gear can be fixed or otherwise mechanically coupled to the lever, and the ratchet gear can be fixed or otherwise mechanically secured to the housing.
[0034] In embodiments, the axle can extend from a first end to a second end, and the lever extends in a u-shape across the axle from a first end at the first end of the axle to a second end at the second end of the axle. The first end of the lever defines a first hole configured to receive the first driven gear and the second end defines a second hole configured to receive the ratchet gear. A length measured along the first axis between bases of the first and second holes is larger, by a first predefined amount, than a length between the first driven gear and the ratchet gear.
[0035] In embodiments, the first end of the lever can define a first axle hole configured to receive the first end of the axle and the second end of the lever defines a second axle hole configured to receive the second end of the axle. A length measured along the first axis between bases of the first and second axle holes is larger, by a second predetermined amount, than a length between the first and second ends of the axle.
[0036] In embodiments, the axle can include a circumferential lip extending around the outer surface of the axle and positioned between the first and second driven gears and defining a first annular groove between the lip and the first driven gear. A width of the annular groove measured along the first axis can be at least equal to the first predetermined amount.
[0037] In embodiments, the attachment device can further include a fin extending between an outer surface of the axle and the base. The fin can be located at an intermediate position between the first and second driven gears. The fin can extend in a plane perpendicular to a plane in which a lower surface of the base extends. The fin can have a bearing surface that contacts and supports the axle.
[0038] In embodiments, the base can have a mounting flange for mounting the attachment device to a substrate, which can include part of a wearable article (e.g., a shoe) or other device as part of a fit system. In embodiments, the mounting flange can be configured to be sewn to the substrate. In other embodiments, the mounting flange can be configured to be mechanically connected to the substrate with snap-fit connection. In still other embodiments, the mounting flange can be configured to be mechanically connected to the substrate with adhesive.
[0039] In embodiments, the attachment device also includes a tension limiter coupled between the lever and the ratcheting adjustment mechanism.
[0040] In embodiments, the attachment device can have a mechanical advantage of over 2:1
[0041] In embodiments, the housing defines two openings through which one or more tension lines may pass for support on the spool. The spool can be configured to draw the one or more tension lines onto the spool through the two openings. In other embodiments, the housing can define a single opening through which a tension line may pass for support on the spool. The spool can be configured to draw the tension line onto the spool through the single opening.
[0042] In embodiments, a preferred profile height may between 5 and 25 mm. If the profile height is under 5 mm, there is a risk of making sharp edges, and there is a risk that the device may become difficult to operate for people with poor dexterity or in applications requiring speed of use. Also, if the profile height is under 5 mm, the device may lack the strength needed for mechanical reliability. Profiles over 25 mm are beyond the point of being reasonable for most wearable applications aesthetically and my lead to safety hazards as discussed above. Nonetheless, in embodiments, the profile height may be up to 29 mm or more. In embodiments, the axle has a diameter of about 3 mm to about 5 mm.

[0043] In embodiments, the axle can be hollow. In other embodiments, the axle can be solid. In embodiments, the axle can define an elongated slotted opening to retain a flat strap tension line. In embodiments, the axle can define at least one hole configured to retain a cable or lace tension line having a round cross section.
[0044] In embodiments, the attachment device can include a pressure distribution pad in contact with the lower surface of the base. The pressure distribution pad can be configured to extend the area of base for pressure reduction.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0045] FIG. **1** is an assembly view of a first embodiment of a lever-operated fit device in accordance with an aspect of the disclosure.
[0046] FIG. **2** is a front, side, and top perspective view of the device of FIG. **1** in an assembled condition.
[0047] FIG. **3** shows the device of FIG. **2** with a cover of the device omitted to show detail of a hypoid gear mechanism.
[0048] FIG. **4** is view of the device of FIG. **2** along line **4-4** in FIG. **2**.
[0049] FIG. **5** is a partial cutaway view of the device of FIG. **2** along line **4-4** in FIG. **2**.
[0050] FIG. **6** is a bottom and side perspective view of a portion of the hypoid gear mechanism shown in FIG. **3**.
[0051] FIG. **7** is view of the device of FIG. **2** along line **7-7** in FIG. **2**.
[0052] FIG. **8** is a side view of the device of FIG. **2** with the lever in a first, rest position.
[0053] FIG. **9** shows the device of FIG. **8** with the lever rotated from the first position to a second position in a first advancing direction.
[0054] FIG. **10** shows the device of FIG. **8** with the lever rotated further in the first winding direction from the second position to a third position.
[0055] FIG. **11** shows details of a user hand movement to disengage and release the spool to permit the spool to rotate in a reverse direction to unwind tension line.
[0056] FIG. **12** is a perspective view of an alternate embodiment of the device of FIG. **1** with a portion of the side of the device removed to show detail of connection between the lever and housing of the device.
[0057] FIG. **13** is a view of the device of FIG. **12** along line **13-13** in FIG. **12**.
[0058] FIG. **14** is an assembly drawing of the lever and one-way bearings used in the device shown in FIG. **12**.
[0059] FIG. **15** shows another embodiment of an adjustment device in accordance with an aspect of the disclosure.
[0060] FIG. **16** shows a method of manually operating a release mechanism of the device of FIG. **15** to release tension in a tension line connected to a spool of the device.
[0061] FIG. **17** is an enlarged view of the device shown in the released configuration shown in FIG. **16**.
[0062] FIG. **18** is an assembly drawing of another embodiment of an adjustment device in accordance with an aspect of the disclosure, viewed from a rear, top, and side of the device.
[0063] FIG. **19** is an assembly drawing of the device of FIG. **18** viewed from a front, bottom, and side of the device.
[0064] FIG. **20** is a top, rear, and side perspective view of the device of FIGS. **18** and **19** along with a tension line connected to the device.
[0065] FIG. **21** is a plan view of the device and tension line shown in FIG. **20**.
[0066] FIG. **22** is a rear elevation view of device and tension line shown in FIG. **20**.

[0067] FIG. **23** is a side elevation view of the device and tension line shown in FIG. **20**.
[0068] FIG. **24** is a plan view of the device of FIG. **22** with the lever of the device translated in the direction of arrow to release tension in the tension line.
[0069] FIG. **25** is a rear elevation view of the device shown in FIG. **24**.
[0070] FIG. **26** shows the device of FIG. **20** with a cover removed to show detail underneath.
[0071] FIG. **27** shows the device of FIG. **24** with a cover removed to show detail underneath.
[0072] FIG. **28** is a partial cutaway of the device shown in FIG. **26**.
[0073] FIG. **29** is a partial cutaway of the device shown in FIG. **27**.
[0074] FIG. **30** is a front, top, and side perspective view of another embodiment of an adjustment device in accordance with an aspect of the disclosure.
[0075] FIG. **31** shows a rear, top, and side perspective view of the device of FIG. **30**.
[0076] FIG. **32** is an assembly drawing of the device shown in FIGS. **30** and **31**.
[0077] FIG. **33** is a plan view of the device of FIG. **30** with the lever removed for clarity of illustration and with the pawls shown in engagement with the gears of the spool.
[0078] FIG. **34** is a plan view of the device of FIG. **30** with the lever removed for clarity of illustration and with the pawls shown disengaged from the gears of the spool.
[0079] FIG. **35** is a plan view of another embodiment of a tension device in accordance with the disclosure. The lever is shown transparent to show details of the device underneath the lever.
[0080] FIG. **36** is a transparent side elevation view of the device shown in FIG. **35**.
[0081] FIG. **37** is a transparent plan view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0082] FIG. **38** is a transparent side elevation view of the device shown in FIG. **37**.
[0083] FIG. **39**A is a transparent plan view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0084] FIG. **39**B is a transparent side elevation view of the device shown in FIG. **39**A.
[0085] FIG. **40**A is a transparent side elevation view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0086] FIG. **40**B is a transparent plan view of the device shown in FIG. **40**A shown with a tension line wound about an axle of the device.
[0087] FIG. **40**C is a transparent side elevation view showing the device shown in **40**A shown with the tension line passing through the device and over the spool.
[0088] FIG. **40**D is a transparent side elevation view showing the lever being rotated and the resulting winding of the tension line about the spool.
[0089] FIGS. **41**A-**41**C show details of a collection volume of an embodiment of a single action tension device in accordance with an aspect of the disclosure.
[0090] FIGS. **42**A-**42**C show details of a collection volume of an embodiment of a single action tension device in accordance with an aspect of the disclosure.
[0091] FIG. **43** is an assembly drawing of another embodiment of a tension device in accordance with an aspect of the disclosure, viewed from a top, front, and side of the device.
[0092] FIG. **44** shows the device of FIG. **43** viewed from the top and side of the device.
[0093] FIG. **45** shows the device of FIG. **43** assembled.
[0094] FIG. **46** shows the device of FIG. **44** assembled.
[0095] FIG. **47** is a front elevation view of the device shown in FIGS. **45** and **46**.
[0096] FIG. **48** is a view of the device of FIG. **47** viewed along line **48-48** in FIG. **47**.
[0097] FIG. **49** shows a one-handed releasing motion to release tension in the device of FIGS. **45** and **46**.
[0098] FIG. **50** shows a view of the device of FIG. **46** viewed along line **50-50** in FIG. **47**.
[0099] FIG. **51** shows a view of the device of FIG. **47** viewed along line **51-51** in FIG. **47**.
[0100] FIG. **52** is an exploded view of the area labeled **52** in FIG. **51**.
[0101] FIG. **53** is a top, front, and side perspective view of another embodiment of a tension

device.
[0102] FIG. **54** is a side elevation view of the device of FIG. **53**.
[0103] FIG. **55** is a view of the device shown in FIG. **53** along line **55-55** in FIG. **54**.
[0104] FIG. **56** is a detailed view of detail **56** in FIG. **55**.
[0105] FIG. **57** is a front elevation view of the device of FIG. **53**.
[0106] FIG. **58** is a view of the device shown in FIG. **53** along line **58-58** in FIG. **57**.
[0107] FIG. **59** is a detailed view of detail **59** in FIG. **58**.
[0108] FIG. **60** is a transparent side elevation view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0109] FIG. **61** is a detailed view of the detail **61** in FIG. **60**.
[0110] FIG. **62** is a plan view of the tension device shown in FIG. **60**.
[0111] FIG. **63** shows the tension device of FIG. **62** connected to a tension line with solid outlined arrows showing a direction of application of forces to the tension device to release tension in the tension line of the device, allowing the tension line to move in the direction of broken line arrows.
[0112] FIG. **64** shows the tension line of FIG. **63** after forces are applied to the tension device to release the tension line.
[0113] FIG. **65** is a transparent side elevation view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0114] FIG. **66** shows the device of FIG. **65** from an opposite side.
[0115] FIG. **67** is a plan view of the device of FIG. **65**.
[0116] FIG. **68** shows a single-handed pulling movement to pull on a release handle in a direction of solid-line arrows.
[0117] FIG. **69** is a transparent side elevation view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0118] FIG. **70** shows the device of FIG. **69** from an opposite side.
[0119] FIG. **71** is a plan view of the device of FIG. **69**.
[0120] FIG. **72** shows a single-handed pulling movement to pull on a release handle in a direction of solid-line arrows.
[0121] FIG. **73** is a transparent side elevation view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0122] FIG. **74** shows the device of FIG. **73** from an opposite side.
[0123] FIG. **75** is a plan view of the device of FIG. **73**.
[0124] FIG. **76** shows a single-handed sliding movement to rotate a release knob in a direction of solid-line arrows.
[0125] FIG. **77** is a transparent side elevation view of another embodiment of a tension device in accordance with an aspect of the disclosure.
[0126] FIG. **78** shows the device of FIG. **77** from an opposite side.
[0127] FIG. **79** is a plan view of the device of FIG. **77**.
[0128] FIG. **80** shows a single-handed sliding movement to rotate a release lever in a direction of solid-line arrows.
[0129] FIG. **81**A is a side elevation view of an embodiment of a tension device mounted on a pressure distribution pad.
[0130] FIG. **81**B is a plan view of the device and pressure distribution pad of FIG. **81**A.
[0131] FIG. **81**C shows an alternate configuration of the tension device and pressure distribution pad of FIG. **81**A where the pressure distribution pad and housing can be bent or curved to accommodate connection or mounting to a curved surface.
[0132] FIG. **82** is a view of a fit system comprised of the tension device of FIGS. **81**A-**81**C and a tension line banded about a leg along line **82-82** in FIG. **83**.
[0133] FIG. **83** show an example use of fit systems using the tension devices of FIGS. **81**A-**81**C with tension lines banded about a leg.

[0134] FIG. **84** illustrates with broken line arrows the direction of forces applied using the pressure distribution pads.
[0135] FIG. **85** illustrates with broken line arrows the direction of forces applied using the pressure distribution pads when the tension device is shifted to a rounded corner of the leg.
[0136] FIG. **86-88** show details of a tension line collection funnel of the tension device of FIGS. **81**A-**81**C.
[0137] FIG. **89** shows details of another embodiment of an adjustment device where material is removed from the lever to reduce weight.
[0138] FIG. **90** shows a loop handle attached to a lever of another embodiment of a tension device.
[0139] FIG. **91** shows another embodiment of a tension device that includes a folding lever, shown in a folded configuration.
[0140] FIG. **92** shows the lever of FIG. **91** in an unfolded configuration.
[0141] FIG. **93** shows another embodiment of a tension device that is configured to receive an extension bar, which is shown disconnected in FIG. **93**.
[0142] FIG. **94** shows tension device of FIG. **92** connected to the extension bar.
[0143] FIG. **95** shows another embodiment of a tension device that is configured to connect to a quick connect latch which is shown disconnected from the tension device.
[0144] FIG. **96** shows the tension device and latch of FIG. **95** connected together.
[0145] FIG. **97** shows another embodiment of a tension device that includes a magnetic hook configured to connect to a magnetic hook connected to a tension line. The magnetic hook connected to a tension line is also shown, but with the hooks shown disconnected.
[0146] FIG. **98** shows the magnetic hooks of FIG. **97** connected.
[0147] Prior Art FIG. **99***a* shows schematic prior art tension devices and fit systems connected to a human body.
[0148] FIG. **99***b* shows schematic exemplary fit systems using tension devices in accordance with the disclosure connected to a human body.
[0149] FIGS. **100-122** show schematic representations of fit systems and line tensioning systems in accordance with the disclosure that are configured for various fields of use.

DETAILED DESCRIPTION

[0150] The present disclosure describes a number of embodiments of adjustment devices that employ a spool that interfaces to and supports at least one tension line. Thus, while some embodiments of the adjustment devices have been shown without connection to a tension line, all of the adjustment devices can be used with one or more tension lines. Note that each one the adjustment devices can be part of a fit system or a line tensioning system as described herein.
[0151] As used herein, a “tension line” refers to a flexible elongate member that can be gathered and wound onto a spool and unwound therefrom. The material of the tension line can be inelastic in nature or possibly have some elasticity. The tension line can be a cord, rope, cable, filament, or lace having a generally round profile, as well as flat straps having rectangular or square profiles. The material of the tension line can be any material typically used as a tension line in the same application. Thus, for a footwear application, the tension line used by the adjustment device in accordance with this description may be made from the same material currently in use for shoe laces. Also, the materials used may differ from those typically used for the application. The materials used for the tension line can include metal (e.g., steel) cable, and polyester webbing.
[0152] As used herein, a “fit system” refers to an adjustment device connected to a wearable article with at least one tension line (flexible elongate members such as straps, cables, wires, etc.) with one or more attachment points or interfaces to the article or device. The adjustment devices used in fit systems
[0153] As used herein, a “line tensioning system” refers to an adjustment device connected to a non-wearable article or structure with at least one tension line (flexible elongate members such as straps, cables, wires, etc.) with one or more attachment points or interfaces to the article, device, or

structure. Similar to fit systems, the attachment points or interfaces may decrease in distance relative to one another or relative to the line tensioning system, which can be referred to as contraction or shortening. The adjustment devices used in line tensioning systems may operate in space without being directly mounted to an article or structure.

[0154] FIGS. **1** to **11** show details of an adjustment device **100** that incorporates a hypoid gear **10** to drive a tension line spool **12** configured to wind a tension line (not shown) about the spool **12**. As shown in FIG. **1**, the attachment device **100** includes a base **14** and a cover **16**, which when connected together to form a housing. The system **100** also includes a winding lever **18**, a driving gear **20**, and a driving axle **22**. The cover **16** includes a top cage portion **16***d* that receives and houses the driving axle **22** for orientation along an axis A-A. The driving gear **20** is fixed to the driving axle **22** with a pin **26**. The top cage portion **16***d* of the cover **16** permits the assembly of the driving axle **22** and gear **20** with the lever **18**. The lever **18** is mechanically coupled to the driving axle **22** and the driving gear **20** such that manual pivoting motion of the lever **18** about the axis A-A drives rotation of the driving axle **22** and the driving gear **20** about the axis A-A.

[0155] The system **100** also includes the driven hypoid gear **10** and tension line spool **12** which are supported by a driven axle **24** that is pivotally coupled to the cover **16**. The hypoid gear **10** is fixed to the driven axle **24** with a pin **28**. The adjustment device **100** is shown fully assembled in FIG. **2** with the lever **18** shown in a first position in which the lever **18** is fully folded in an initial or rest position relative to the cover **16**.

[0156] The driving axle **22** extends along the axis A-A through the center of the driving gear **20**. The axis A-A extends parallel to a plane in which a lower surface **14***a* of the base **14** extends. Due to the fixation of the driving gear **20** to the driving axle **22**, the driving axle **22** and the driving gear **20** rotate together in unison about the axis A-A. The driven axle **24** extends along an axis B-B that is perpendicular to the axis A-A. The driven axle **24** extends coaxially through the center of the hypoid gear **10**. Due to the fixation of the hypoid gear **10** to the driven axle **24**, the driven axle **24** and the hypoid gear **10** rotate together in unison about the axis B-B. The hypoid (driven) gear **10** is fixed to the driven axle **24** at a position that ensures that the driving gear **20** remains enmeshed or otherwise engaged with the hypoid gear **10** at all times.

[0157] As shown in greater detail in FIG. **3**, the axes A-A and B-B do not intersect one another, but are positioned in spaced relation to one another to position the teeth of the driving gear **20** and the hypoid gear **10** into meshed engagement. The driving gear **20** has helical teeth that are configured to always be enmeshed with teeth of the hypoid gear **10**. The driving gear **20** is configured to rotate about the axis A-A to drive rotation of the hypoid gear **10** about the axis B-B in a first rotational direction.

[0158] The driven axle **24** (and its rotational axis B-B) also extends coaxially through the center of the spool **12**. The spool **12** is not directly secured to the driven axle **24**. Instead, the spool **12** can be selectively and indirectly coupled to the driven axle **24** with an engagement member **36** that is fixed to a lower end of the driven axle **24**. When the engagement member **36** is configured to couple the spool **12** to the driven axle **24**, the spool **12** rotates in unison with the rotation of the driven axle **24** (and also in unison with the rotation of the hypoid gear **10** coupled thereto). In this manner, the engagement member **36** is configured to selectively engage and join the spool **12** to the driven axle **24** to prevent relative rotation between the driven axle **24** and the spool **12**. Specifically, the engagement member **36** can have protrusions or teeth **36***a* and the spool **12** has corresponding recesses or teeth **12***a* (FIG. **6**) that are configured to mate with the protrusions or teeth **36***a* of the engagement member **36** in a first configuration of the engagement member **36**. A biasing member **38** (e.g., a spring) is engaged between the bottom of the engagement member **38** and the top of the base **14**. The biasing member **38** biases the engagement member **36** (and thus the driven axle **24**) upwardly so that the protrusions or teeth **36***a* of the engagement member **36** are engaged with the recesses or teeth **12***a* of the spool **12**. The biasing member **38** also translates the spool **12** axially upward into contact with an underside of the hypoid gear **10** so that the spool **12** will not move axially out of engagement with the engagement member **36**.

[0159] The cover **16** defines a central opening **16***b* aligned with the axis B-B. The central opening **16***b* is coaxial with the driven axle **24**, the spool **12**, and the hypoid gear **10**. The cover **16** also defines opposed openings **16***c* in sides of the cover that align with the axis A-A. The side openings **16***c* are coaxial with the driving axle **22** and the driving gear **20**. The driving axle **22** extends along the axis A-A and has ends **22***a* that extend through the side openings **16***c* of the cover **16**. The driving axle **22** is supported near its ends by bearings **30** seated in grooves (not shown) formed in the wall of the cover adjacent the side openings **16***c* of the cover **16**.

[0160] The driven axle **24** extends through the opening in the top of the cover **16**. A push button **40** is attached to the upper end of the driven axle **24**. The engagement member **36** can be disengaged from the spool **12** by translating the driven axle **24** along axis B-B in the downward direction by depressing the push button **40**. When the push button **40** is not depressed, the engagement member **36** remains engaged with the spool **12** in the first configuration so that the spool is rotationally fixed to the driven axle **24**. Also, since the hypoid gear **10** is rotationally fixed to the driven axle **24** with the pin **28**, rotation of the hypoid gear **10** directly causes the driven axle **24** to rotate in unison with the hypoid gear **10**. Thus, rotation of the hypoid gear **10** about the axis B-B in a first rotational direction causes rotation of the spool **12** in the first rotational direction when the spool **12** is engaged with the engagement member **36**. However, if the push button **40** is depressed to disengage the spool **12** from the engagement member **36** in a second configuration, rotation of the hypoid gear **10** will not cause the spool **12** to rotate in the first direction in unison with the hypoid gear **10** and the driven axle **24**, since the spool **12** is disengaged from the driven axle **24** permitting relative rotation between the driven axle **24** and the spool **12**. Thus, when the spool is in the second configuration, the spool **12** rotates freely in either of the first direction or a second direction opposite the first direction, which can allow a user to unwind tension line from the spool **12**, either partially or fully as long as the button **40** remains depressed. Once a user releases the button **40**, the spring **38** will reconfigure the spool **12** into the first configuration so that the spool **12** can only be rotated with the shaft in the first direction to wind the tension line.

[0161] As shown in greater detail in FIG. **7**, a pawl **32**, resiliently biased with spring **34**, is pivotally coupled to an underside of the cover **16**. The pawl **32** has a curved underside **32***a* that is configured to allow the pawl **32** to ride over the teeth of the hypoid gear **10** when the hypoid gear **10** rotates about the axis B-B in a first advancing direction (to the right in FIG. **7**). The pawl **32** has a sharp distal edge **32***b* that is angled to fit between adjacent teeth of the hypoid gear **10**, which prevents rotation of the hypoid gear **10** in a second direction (to the left in FIG. **7**) opposite the first direction. The spring **34** maintains engagement between the pawl **32** and the teeth of the hypoid gear **10**. Thus, the pawl **32** aids in maintaining tension in the tension line during winding by preventing the hypoid gear **10** (and also the engaged spool **12**) from reversing direction.

[0162] Rotation of the hypoid gear **10** is accomplished by driving (rotating) the driving gear **20** using the lever **18**. The lever **18** is connected to the driving axle **22** at spaced apart regions thereof and preferably at opposing ends thereof. The lever **18** is shown u-shaped for convenience of use but can be of other shapes. The lever **18** has openings **18***c*, **18***d* at its ends **18***a*, **18***b* that are aligned along the axis A-A. The inner surface (e.g., **18***e* is shown and is the mirror image for opening **18***c*) of the openings **18***c*, **18***d* are circular and define a plurality of teeth **18***f* equally spaced circumferentially. The teeth **18***f* are rounded one-way slopping gear teeth (gear teeth with a coast side and a drive side). Each opening **18***c*, **18***d* is configured to receive a corresponding ratcheting pawl member **42** that has pawls **42***a* that engage and are driven by the drive side of the teeth on the inner surface **18***e* of the openings **18***c*, **18***d* when lever **18** is rotated a first direction (i.e., clockwise in FIG. **1**) about axis A-A. Otherwise, if the lever **18** is rotated in a second direction about axis A-A opposite the first direction (i.e., counter-clockwise in FIG. **1**), the coast side of the gear teeth **18***f* ride or skip over the pawls **42***a* allowing for a ratcheting operation of the lever **18**. Each pawl member **42** defines a central through hole **42***b* that is keyed or otherwise shaped to fit a mating end

22*a* of the driving axle **22**. Thus, when the pawls **42***a*, **42***b* are engaged when the lever **18** rotates in the first direction about axis A-A, the driving shaft **22** and driving gear **20** rotate together in unison with the pawl members **42** and the lever **18** about axis A-A. Further, since the driving gear **20** is enmeshed with the hypoid gear **10** at all times, the rotation of the driving gear **20** causes rotation of the hypoid gear **10** about the axis B-B, which thereby causes the engaged spool **12** to rotate in the first rotational direction about axis B-B. Any tension line connected to the spool will be drawn toward and wound around the spool **12**.

[0163] Once the spool **12** has been wound to tighten the tension line to a desired amount by the user, or if the lever **18** cannot be rotated any further (i.e., because a portion of the article coupled to the adjustment device **100** interferes with the lever **18** or the volume between the spool **12** and the housing **16** is full of tension line), further rotation of the lever **18** in the first direction about axis A-A stops and the pawl **32** locks the hypoid gear **10** from unwinding in the second direction about axis B-B. The lever **18** can then be rotated about axis A-A in a second direction back toward the first rest position (i.e., counterclockwise). As the lever **18** is rotated about axis A-A in the second direction back toward the first rest position, the coast side of the inner teeth of the lever **18** ride over the pawls **42***a* as the pawl member **42** and the driving axle **22** remain rotationally stationary relative to the cover **16** due to the locked position of the hypoid gear **10** enmeshed with the driving gear **20**. Thus, the pawl members **32** and **42** permit a one-way winding of the spool **12** and a ratcheting operation of the lever **18**. Additional rotation of the spool **12** in the first rotational direction about axis B-B to wind additional tension line can be accomplished by repeating the rotation of the lever **18** about its pivot axis A-A back and forth as many times as desired to achieve the desired tension in the tension line and/or desired amount of tension line collected

[0164] Any tension in the tension line connected to the spool **12** can be reduced by disengaging the spool **12** from the engagement member **36** by depressing the push button **40**, which permits the spool **12** to rotate relative to the driven axle **24** and the hypoid gear **10** in the second direction about axis B-B opposite the first direction to loosen the tension line. Once the spool **12** is disengaged, the spool **12** is free to rotate in the second direction opposite the first direction to pay out tension line to reduce tension.

[0165] The cover **16** and the base **14** are removably coupled together to form a housing. In the embodiment shown, the base **14** includes snap fit connectors **14***b* formed as projections that are configured to snap into recesses **16***a* (FIG. **7**) formed in the underside of the cover **16** to join the cover to the base. Other coupling arrangements are contemplated, including threaded fasteners and other snap fit arrangements. The base **14** has a flange **14***c* that may be formed as a flexible material, such as plastic or durable fabric that can be sewn to an article, such as a wearable article (e.g., shoes, belts, straps, helmets). Alternatively, the flange **14***c* may be adhesively connected along its lower surface **14***a* to an article. Also, a portion of an article may be coupled between the cover and the base **14** using the snap fit connectors **14***b* as both a means of coupling the base **14** to the cover **16**, but also as a means of interconnecting the article between the base **14** and cover **16**. For example, an article may have a mounting flange having four holes formed that match the pattern of the four projections **14***b* in the base **16** to permit the projections **14***b* to pass through the holes in the flange of the article and to then snap into the recesses **16***a* of the cover, thereby locking the article between the base **14** and the cover **16**.

[0166] FIGS. **12-14** show an alternative adjustment device **100′** to the adjustment device **100**. In FIGS. **12-14**, elements corresponding to adjustment device **100** are referenced with like reference numbers appended with "′". Specifically, adjustment device **100′** differs from adjustment device **100** as follows. The adjustment device **100′** includes one-way bearings **42′** as a substitute for pawl members **42** and the inner gear teeth **18***f* of lever **18**. In adjustment device **100′**, the lever **18′** has inner openings (opening facing the center of the housing **16′**) **18***c*′, **18***d*′ formed in the ends **18***a*′, **18***b*′ of the lever **18′** that are keyed to receive outer race **42***a*′ of one-way bearings **42′**. The outer race **42***a*′ of the bearings **42′** are keyed with grooves to mate with corresponding protrusions in the openings **18***c*′, **18***d*′ to prevent relative rotation between the outer race **42***a*′ and the lever **18**′. A driving axle **22**′ is received and rotationally fixed to inner races **42***b*′ of the bearings **42**′. The operation of the lever **18**′ to drive and rotate the spool **12**′ about axis B-B is the same as in device **100**, however the one-way winding function provided by the pawl members **42** and inner teeth **18***f* are provided by an internal mechanism of the one-way bearings **42**′, as is known in the art.

[0167] FIGS. **15-17** show another embodiment of an adjustment device **200** with dual-direction adjustment (the device has pathways to wind the strap from two different directions, e.g., left, and right in FIG. **15**). As shown in FIG. **15**, the device **200** includes a base **214** with a ratchet gear **213**, a cover **216** (shown transparent in FIG. **15**) or housing connected to the base **214**, a winding lever **218** having a side-facing driving gear **220**, and a driven axle **224** connected to a first driven **210** gear and a second driven gear **211** forming a winding spool **212** for winding a tension line **223** (e.g., a strap). The driven axle **224** extends from a first end **224***a* to a second end **224***b*. The first and second driven gears **210** and **211** are fixed to the driven axle **224** and rotate in unison together with the axle **224** coaxially about a central axis of the axle D-D, that extends perpendicular to axis C-C. The first driven gear **210** and the second driven gear **211** are located at intermediate positions between the first and second ends **224***a*, **224***b* of the driven axle **224**. Thus, the driven gear **210** is spaced from the first end **224***a* of the axle **224** and the second driven gear **211** is spaced from the second end **224***b* of the axle **224**.

[0168] The adjustment device **200** is shown fully assembled in FIG. **15** with the lever **218** shown in a first position in which the lever **218** is fully folded in an initial or home position relative to the base **214**. The driven axle **224** has a longitudinal split opening **224***a* to receive a tension line **223** (e.g., a strap) therethrough. The split opening **224***a* can be pinched to close on the strap **223** to retain the strap relative to the axle **224**.

[0169] The driving gear **220**, driven gears **210**, **211**, and ratchet gear **213** have side-oriented teeth that extend generally parallel to the longitudinal axis D-D. The driving gear **220** and first driven gear **210** have gear teeth have oppositely sloping coasting surfaces and driving surfaces compared to the gear teeth of the second driven gear **211** and ratchet gear **213**. The coasting surfaces extend at an acute angle with respect to the axis C-C. The driving surfaces extend substantially (within about 15 degrees) parallel to the longitudinal axis D-D. The side-facing orientation of the gear teeth differ from prior art gears that have gear teeth that extend radially outward in a direction perpendicular to the axis of rotation of the gear. The side facing gears **220**, **210**, **211**, and **213** used in the adjustment device **200** allow for a lower profile and compact design as compared to what would be required using prior art gear arrangements.

[0170] The adjustment device **200** also includes the u-shaped lever **218** that extend from a first end **218***a* to a second end **218***b*. The first end **218***a* has a first bore **218***al* in which the side-oriented driving gear **220** is recessed. The driving gear **220** is configured to engage and drive the first driven gear **210** of the spool **212**. The first end **218***a* also has a second bore **218***a***2** configured to receive the first end **224***a* of the driven axle **224**. The second end **218***b* has a first bore **218***b***1** coaxially aligned with the driven axle **224** and configured to receive the ratchet gear **213**. The second end **218***b* also defines a second bore **218***b***2** formed as a shallow spring seat in the base of the first bore **218***b***1** to receive a spring **238** extending between the spring seat **218***b***2** and an outer side of the ratchet gear **213**, which is an outer side of the cover **216**. A third bore **218***b***3** is defined in the base of the second bore **218***b***2** that is configured to receive the second end **224***b* of the driven axle **224**.

[0171] The ratchet gear **213** is fixed on the inside of the cover **216** and is configured to mesh with the second driven gear **211**. The spring **238** biases the entire lever **218** axially along axis D-D in a direction toward the ratchet gear **213** so that the driving gear **220** is engaged with the first driven gear **210** and the second driven gear **211** is engaged with the ratchet gear **213**. When the lever is rotated from the first position in the direction of the curved arrow about axis D-D, the driving gear **220** drives the first driven gear **210** in the same direction. The entire spool **212** rotates with the first driven gear **210** to wind the tension line **223** in the direction of the opposing arrows. Also, when the lever rotates in the first direction about axis D-D, the coast side of the teeth of the second driven gear **211** skip over the coast side of the teeth of the ratchet gear **213**. When lever **218** and the driving gear **220** rotates in a second direction about axis D-D opposite the first direction, the coast side of the teeth of the driving gear **220** skip over the coast side of the teeth of the first driven gear **210** so that the tension line **223** is not unwound. Also, when the lever **218** is rotated in the second direction, the drive side of the gears of the ratchet gear **213** and the second driven gear **211** engage to prevent the axle **224** from rotating in the second direction about axis D-D. This allows the lever **218** to reset back to the first position without reducing the tension in the tension line **223**.

[0172] As shown in FIGS. **16** and **17**, the entire lever **218** can be translated along axis D-D relative to the base **214** and the cover **216** to simultaneously disengage the driving gear **220** from the first driven gear **210** and to disengage the second driven gear **211** from the ratchet gear **213**. Such disengagement permits the spool to rotate in the second direction about axis D-D to unwind the tension line **223**. Specifically, FIG. **16** shows a method of releasing the tension in the tension line by way of pressing on the lever with a finger or hand of a user to impart a force on the lever **218** at least partly in a direction of the arrow, which is in a direction parallel to the axis D-D. When the lever **218** translates, the spring **238** becomes compressed as the second end **224***b* of the axle **224** is received in the third bore **218***b***3** and the ratchet gear **213** is received in the first bore **218***b***2**. Also, when lever **218** is translated, the first end **224***a* of the axle **224** slides in a direction away from a bottom of the second bore **218***a***2** as the first driven gear **210** moves out of engagement with the driving gear **220** and out of the first bore **218***al* of the first end **218***a* of the lever **218**. This release of the spool **212** from engagement with the driving gear **220** and the ratchet gear **213** is made possible by the spaces of the first bores **218***a***1**, **218***b***1** of the lever **218** that are specifically designed to allow the lever **218** to translate relative to the spool **212**. Upon release of the lever **218** in FIG. **16**, the spring **238** will push the driving gear **220** into engagement with driven gear **210** and push the driven gear **211** into engagement with ratchet gear **213** (as shown in FIG. **15**).

[0173] FIGS. **18-32** show an alternate adjustment device **300** to that shown in FIGS. **15-17** and described above. In FIGS. **18-32** like elements to those of device **200** will be referred to with like numbers incremented by “100”. The adjustment device **300** has corresponding elements and function as the device **200** described above but has the following additional features.

[0174] As shown in FIGS. **18** and **19**, the device **300** includes a base **314** and a cover **316** that connect together form a housing to house the spool **312** and tension line in a generally annular collection volume between the outer surface of the axle **324** of the spool **312** and the inner surfaces of the base **314** and the cover **316**. The base **314** may be connected to the cover **316** with a snap fit connection or with other fasteners, such as threaded fasteners.

[0175] The cover **316** extends longitudinally along axis E-E from a first open end **316***a* to a second open end **316***b*. The cover **316** defines a u-shaped hole **316***al* at the first end of the cover **316***a* and a circular hole **316***b***1** at the second end **316***b* of the cover. The u-shaped hole **316***al* and the circular hole **316***b***1** have smooth mating and bearing surfaces for supporting the first and second ends **324***a*, **324***b* of the driven axle **324**, which extends coaxially with the cover **316** along axis E-E. The u-shaped hole **316***al* provides an opening at the bottom of the cover **316** that allows the first end **324***a* of the driven axle **324** to be assembled into the cover **316** after a tension line **323** (e.g., lace or cable) has been joined to the axle **324**. The second end **324***b* of the driven axle **324** extends through the circular hole **316***b***1**. Like the device **200**, a ratchet gear **313** with side-facing teeth (facing the first end **316***a* of the cover **316**) is located on an inner side wall of the cover **316** at the second end **316***b* of the cover **316**. The ratchet gear **313** is configured to engage the second driven gear **311** of the spool **312** when the spool **312** is assembled between with the base **314** and the cover **316**.

[0176] The base **314** is has a generally planar bottom surface **314***a* (FIG. **19**) and top surface. The lower surface **314***a* of the base **314** extends in a plane parallel to the axis E-E of the axle **324**. The base **314** has a peripheral flange **314***c* that can serve as a stitch flange wherein the stitching flange can be integrated into an article, such as a garment.

[0177] The base **314** includes a central fin **314***a* or wall that extends perpendicular to the bottom surface **314***a* of the base **314**. The fin **314***a* also extends perpendicular to the longitudinal axis E-E of the axle **324**. The cover **316** may also include a central fin that aligns with the fin **314***a* of the base **314**. The fin **314***a* has a semicircular cutout **314***al* that is configured to engage and bear against a lower half of the outer surface of the axle **324**. The cutout **314***al* matches the contour of the profile of the driven axle **324**. Thus, when the device **300** is assembled, the fin **314***al* at least partially surrounds the outer circumference of the axle **324** to thereby divide the annular collection volume into two parts. The fin **314***a* may be positioned centrally on the axle **324** to divide the collection volume into two equal parts. Dividing the collection volume is advantageous because it can help maintain the tension line **323** (e.g., lace or cable) organized and avoid issues of the tension line **323** collecting on one side of the collection volume, thereby prematurely jamming the collection channel volume. The fin **314***a* may also act as a bearing support for the axle **324** at an intermediate position between the ends of the axle **324**, thereby improving the structural integrity of the axle **324** and possibly allowing for use of lighter-weight materials that may reduce the cost of manufacturing the adjustment device **300**. As an alternative, the fin **314***a* may be part of the axle **324** and extend as a disc from the axle **324** at an axial location along axis E-E between the driven gear **310** and driven gear **311**.
[0178] The cover **316** also defines entrance and exit holes **325** (FIG. **19**) for the tension line **323** to pass into the collection volume, as shown more fully in FIGS. **20**, **28**, and **29**. The holes **325** may be elongated slots that are elongated in a direction parallel to the axis E-E, as shown in FIG. **19**. The slotted holes **325** may allow the tension line **323** to shift slightly in the axial direction to accommodate different angles and forces in the tension line **323** as the tension line **323** passes through the cover as it is being collected around the axle **324**. For example, the tension line shown in FIG. **20** extend near the inner ends of the slotted holes **325**, whereas in FIG. **24**, the tension line shown extend near the outer ends of the slotted holes **325**.
[0179] The axle **324** defines two holes **324***c* (FIGS. **18**, **27**) passing through for connection of the tension line **323** to the axle **324**. The axle **324** is configured to terminate the tension line **323** (e.g., lace or cable) at the axle **324** or to allow for a continuous tension line (e.g., cable or lace) to pass through the holes **324***c* of the axle **324** whereby the tension line **323** will be appropriately collected around the axle **324** upon rotation of the axle **324** relative to the cover **316** and the base **314**.
[0180] In the embodiment shown, there are two through holes **324***c* passing through the axle **324** at an angle that enables the tension line **323** to exit the holes **324***c* at an angle that is sufficiently tangent to the outer circumference of the axle **324** in order to mitigate weakening the tension line **323** upon winding (i.e., collection) of the tension line **323**. The end of the holes **324***c* (shown in FIG. **19**) also includes a blind hole **324***d* that is larger than the corresponding through holes **324***c* such that a lace knot or cable termination feature (swaged onto the cable) can recess into this portion of the feature for applications that choose to terminate the lace or cable at the axle **324**. For embodiments where it is desired to pass the tension line **323** through the axle **324** in one continuous cable, a trough **324***e* (shown as an elongated recess below the surface of the axle **324**) is formed in the axle to allow the tension line **323** to route from one hole **324***c* to the other hole **324***c* so that the tension line **323** does not interfere with the fin **314***a* that extends from the base **314**. In the alternative embodiment were the fin **314***al* extends from the axle **324** instead of the base **314** or cover **316**, a split or dart in the fin could also provide clearance for a continuous cable to be passed from one side hole to the other in the axle **324**.
[0181] The axle **324** has additional distinguishing features from the axle **224** of the previously described device **200**. In the embodiment shown, the axle **324** includes a first lip extending circumferentially around the axle **324**. The first lip extends radially from the outer surface of the axle **324**. The first lip **332** (FIG. **27**) is spaced axially along axis E-E from the first driven gear **310** and is positioned to block the tension line **323** from collecting into an annular groove **333** between the first lip **332** and the first driven gear **310**. The groove **333** extends a predetermined amount

along axis E-E that is required to allow for translation of the axle **324** during disengagement of the driving gear **320** and first driven gear **310**. This annular groove **333** along the axle **324** should not contain tension line **323** to ensure full translation of the **318** lever and simultaneous disengagement of the spool **312** from the driving gear **320** and the ratchet gear **313**. It will be appreciated that if the first lip **332** is omitted, the tension line **323** could collect onto the spool **324** up to the back side of the driving gear **320**, which could inhibit relative axial translation between the axle **324** and the lever **318**.

[0182] The axle **324** also includes a second lip **334** (FIG. **27**) extending circumferentially around the axle **324** along the back side of the second driven gear **311**. The second lip **334** includes a filleted corner to facilitate manufacturing.

[0183] The lever **318** has ends **318***a* and **318***b* have similar construction to ends **218***a* and **218***b* of lever **218**. The lever **318** has the same function as the lever **318** for winding the axle **324**. In addition, the second end **318***b* of the lever **318** in the embodiment shown has a shoulder **318***c* that extends axially (parallel to axis E-E) from a circular outer edge **318***d* of the second end **318***b*. The shoulder **318***c* extends circumferentially about 180 degrees around the outer edge **318***d*. The shoulder **318***c* extends to cover and protect (e.g., from incursion of debris) a space between the second end **318***b* of the lever **318** and the second end **316***b* of the cover **316**. Due to the location and extent of the shoulder **318***c* relative to the sides of the cover **316**, the shoulder **318***c* will interfere with the cover **316** and prevent the lever **318** from being translated axially along axis E-E when the lever **318** is rotated about axis E-E more than 45 degrees from the initial rest position shown in FIG. **20**, for example. However, the shoulder **318***c* does not otherwise interfere or restrict any other movement of the lever **318** required for rotation of the spool **312** in a first direction where tension line is collected or otherwise wound on the spool **312**.

[0184] An example adjustment device **300** may have the following features and dimensions, which may be for an adjustment device used on an article of footwear, such as a shoe or boot. The lever may have an arm length of 19 mm measured from the central axis extending through first and second ends of the lever. The axle diameter may be about 8 mm. The driving and driven gears may have 16 teeth. The degree of rotation per gear tooth may be 22.5 degrees. The spool diameter may have a range of 8 mm (when the axle is empty) to 12 mm when the axle is full. The spool length between lips **332** and **334** may be 16 mm. The collection volume may be approximately 1005 cubic mm. It is notable that that the volume of tension line collection is relatively small because the volume requirement for collection of lace for a shoe, such as a bicycle shoe, is low. This volume is still more than double that of the low-profile designs for some prior art devices.

[0185] The example device may have approximate dimensions of length (measured along the longitudinal axis), width, and height of 33 mm, 25.5 mm, and 13 mm, respectively. When the spool is empty, the mechanical advantage starts at 2.1:1, and when the spool is full (has collected tension line) the mechanical advantage is 1.7:1.

[0186] In the example embodiment of device **300**, all parts except for the spring **338** may be made as a thin walled part made from injection molded plastic such as nylon. The axle **324** may alternately be a solid plastic part or be made of metal. Alternatively, any combination or all parts of the device **300** may be made of metal.

[0187] FIGS. **30-34** show views of another adjustment device **400** that includes a housing comprised of upstanding sides **416***a*, **416***b* and a base **414**, a ratcheting winding lever **418** pivotally connected to the sides **416**, and a spool **412** pivotally connected to the sides **416**. The sides **416***a*, **416***b* extend from the base **414**, which is generally planar. The base has a lower surface **414***a* for attachment to an article, such as a wearable article. The spool **412** includes a central axle **424** that extends between the sides **416***a* and **416***b* of the housing **416**. The axle **424** extends from a first end **424***a* to a second end **424***b* along a longitudinal axis F-F (FIG. **35**) that is parallel to the plane of the lower surface **414***a* of the base **414**. The spool **412** includes a driven gear **410** and a ratchet gear **413** fixed to the axle **424**. The driven gear **410** and the ratchet gear **413** are spaced from the ends

424*a* and **424***b* of the axle **424**. The gears **410** and **413** have teeth that extend perpendicular to the longitudinal axis F-F. The gears **410** and **413** have curved teeth that are oriented in the same direction. The teeth have a coasting side and a driving side.

[0188] As shown in greater detail in FIG. **32**, the lever **418** has a first end **418***a* with first and second hinge flanges **419***a*, **419***b* having axially aligned openings **421***a*, **421***b* through which the first and second ends **424***a*, **424***b* of the axle **424** are received. Thus, when the device **400** is assembled, a first hinge flange **419***a* is positioned between a first side **416***a* of the housing **416** and the driven gear **410** and the second hinge flange **419***b* is positioned between the second side **416***b* of the housing **416** and the ratchet gear **413**. The ends **424***a*, **424***b* of the axle **424** extend outwardly beyond the hinge flanges **419***a*, **419***b* and are seated in holes (not shown) of the sides **416***a*, **416***b* of the housing **416**. The axle **424** may be a solid axle with through holes for receiving a tension line (not shown).

[0189] The lever **418** has a second end **418***b* opposite the first end **418***a*. A pawl **440** is pivotally mounted with a hinge pin **441** to the underside of the lever **418** at the second end **418***b* thereof. Specifically, a hinge **439** extends from the underside of the lever **418**. A hinge pin **441** extends through the knuckles of the hinge **439** and through the pawl **440**, a torsional spring **442**, and a coil spring **443**, which are all positioned side by side between the knuckles of the hinge **439**. The knuckles of the hinge **439** are spaced far enough apart to provide the pawl **440** with a range of translational movement parallel to axis F-F. The coil spring **443** urges the pawl **440** outward into alignment with the teeth of the driven gear **410**.

[0190] The pawl **440** is also biased by the torsion spring **442** to engage the teeth of the driven gear **410**. The pawl **440** is configured to engage the drive side of the teeth of the driven gear **410** so that the driven gear **410** and the axle **424** (and thus the entire spool **412**) are rotated in a first direction about axis F-F as the lever **418** is pivoted about the axis F-F in a first rotational direction (i.e., clockwise in FIG. **33**). The pawl **440** is configured to skip across the coast side of teeth of the driven gear **410** when the lever **418** is pivoted about the axis F-F in a second rotational direction opposite the first direction.

[0191] A spring biased ratchet pawl **450** is mounted to the base **414** to engage the ratchet gear **413**. Specifically, when the spool **412** is rotated in the first direction about axis F-F, the pawl **450** is configured to skip over the teeth of the ratchet gear **413**. When the lever **418** rotates in the second direction about axis F-F, or when the lever **418** is stationary, the pawl **450** engages the drive side of the teeth of the ratchet gear **413** to prevent the axle **424** (and thus the spool **412**) from rotating in the second direction (i.e., prevent the axle and spool from reversing and loosening tension in the tension line). The ratchet pawl **450** is mounted to the base **414** on a sliding mount like the lever-mounted pawl **440** so that the pawl **450** is configured to translate axially parallel to axis F-F. A hinge pin **451** extends through the pawl **450**, a torsional spring **452**, and a coil spring **453**. The pawl **450** is configured to translate along the hinge pin **451**, which is parallel to axis F-F. The coil spring **453** urges the pawl **450** into engagement with the teeth of the ratchet gear **413**.

[0192] Two coaxially aligned push buttons **460**, **461** are mounted, respectively, to the sides **416***a*, **416***b*. A first push button **460** has a head **460***a* and a grooved stem **460***b* that extends through the first side **416***a* of the housing **416** and is connected thereto with a circlip **462**. The button **460** is urged outwardly away from the first side **416***a* with a spring **464** around the stem **460***b* and positioned between the head **460***a* and the first side **416***a*. A second push button **461** has a head **461***a* and a grooved stem **461***b* that extends through the second side **416***b* of the housing **416** and is connected thereto with a circlip **463**. The button **461** is urged outwardly away from the second side **416***a* with a spring **465** around the stem **461***b* and positioned between the head **461***a* and the second side **416***b*.

[0193] The push buttons **460** and **461** are coaxially aligned along an axis parallel to axis F-F. The first push button **460** is configured to align with the first pawl **440** when the lever **418** is rotated to a fully closed or folded position (FIG. **34**). When the lever **418** is in the fully closed or folded position, the push button **460** can be pushed inwardly to translate the pawl **440** in a direction parallel to the longitudinal axis F-F, which disengages the first pawl **440** from the driven gear **410**. The second push button **461** aligns with the second pawl **450**. When the second push button **461** is pushed inwardly, the pawl **450** translates inwardly out of engagement with the ratchet gear **413**. When both the first and second push buttons **460**, **461** are pushed inwardly (opposing forces are applied to the buttons), both gears **410** and **413** are disengaged from the first and second pawls **440**, **450**, allowing the spool **412** to rotate freely about axis F-F so that the tension line can be unwound. The push buttons **460** and **461** are arranged so that they can be pushed manually using a one-handed pinching motion of a user, using the thumb and index finger, for example.

[0194] FIGS. **35-38** show an alternative adjustment device **500** to adjustment device **400**, where like elements are shown incremented by “100”. Specifically, the adjustment device **500** includes a tension limiter to avoid overtightening the tension line.

[0195] Also, the adjustment device **500** include a different pawl disengagement mechanism from that of device **400**. Rather than use torsional springs, the adjustment device uses only coil springs for its pawl disengagement mechanism. Specifically, the device **500** includes a spool **512** with an axle **524** fixed to a driven gear **510** and a ratchet gear **513**. A pawl **540** is used to drive the driven gear **510** as the lever **518** is rotated about axis F-F in a first advancing direction. A ratchet pawl **550** prevents the unwinding of the spool **510** after the tension line is wound onto the spool **512**. The ratchet pawl **550** is mounted to the base **514** with a pawl release housing **582** and a release braking mechanism **583**, while the ratchet pawl **540** is mounted to the lever **518** with a pawl release housing **582** and a release braking mechanism **583**. The release housing and braking mechanisms on both sides of the spool **512** are constructed and operate the same way so the remaining discussion is of the engagement and disengagement and braking mechanism of the ratchet pawl **550**.

[0196] The ratchet pawl **550** permits rotation of the spool **512** with the lever **518** in a first rotational direction to wind tension line and blocks rotation of the spool **512** in the second direction opposite the first direction as previously described. In order to release the pawl **550**, the user can push on the release button **561** located on the side of the base **514**. The pawl housing **582** includes helical compression springs **584** that biases the pawl **550** into the drive side of the gear teeth of ratchet gear **513**, and includes helical compression springs **585** that bias the pawl **550** (in a direction parallel to the axis F-F) back into alignment with the gear **513** when the pressure has been removed from the release button **561**.

[0197] The pawl disengagement mechanism is also connected to a release braking mechanism that is engaged with the gears **510** and **513** when the pawls **540**, **550** are disengaged from the gears **510**, **513**. The release braking mechanism includes a friction brake **583** connected to the push button **561** that simultaneously translates into engagement with the side of the gear **513** as the pawl **550** translates out of engagement with the gear **513**. The release braking mechanism provides the user with the ability to control the speed and amount of tension line released upon disengagement of the pawls **540**, **550** in order to prevent a rapid or complete unwinding of the tension line upon release.

[0198] FIGS. **39**A-**39**B show an alternate device **500**′ that is the same as the device **500** but differs as follows. Specifically, the device **500**′ omits the tension limiter of device **500** and includes a spool **512**′ with an axle **524**′ configured to wind a flat strap tension line **523**′ with a looped end instead of a lace or cable.

[0199] The spool **512**′ includes a strap capturing mechanism that includes an off-axis pin **522**′ that is rigidly mounted parallel to and radially spaced from the axle **524**′. The pin **522**′ extends from driven gear **510**′ to ratchet gear **513**′. The device **500**′ is configured to wind a strap **523**′ that has ends formed as a stitched or fastened loop **523***a*′, such as shown in FIG. **39**B. The axle **524**′ extends through the loop **523***a*′ to retain the strap **523**′ to the axle **524**′. Due to the off-axis position of the pin **522**′, the pin **522**′ catches the strap **523**′ that is looped around the axle **524**′ and extending in opening **514***d*′ during the first rotation of the pin **522**′ about the axis axle **524**′, as shown in greater detail in FIGS. **39**B. This arrangement allows the device **500**′ to wind and release a single strap along a single pathway (i.e., from one direction).

[0200] In prior art, tension line strap is captured by a split axis wherein a strap can pass through but as the axis is rotated, the strap is captured and collected around. In device **500**′, the profile height of the adjustment device **500**′ can be greatly reduced by using a solid axle **524**′. This arrangement avoids the need for the user to manually feed the strap through a split axis or other mechanism in order to use the device **500**′. The solid axle can be strong enough to maintain the strap **523**′ with a much smaller diameter than is required for an axle with a greatly compromised strength due to a split axis or hole through the axis.

[0201] FIGS. **40**A to **40**D show yet another alternate device **500**″ having features corresponding to device **500**′. Notably, the base **514**″ defines a tension line pathway that permits dual direction tension line adjustment so that the tension line can be wound into (and dispensed from) the device from two directions. The device **500**″ has a spool **512**″ that is the same as spool **512**′ of device **500**′. However, the strap **523**″ differs from strap **523**′ in that strap **523**″ does not have a closed or looped end fastened to the axle **524**″. Instead, as shown in FIG. **40**C, the strap tension line **523**″ extends through the device **500**″ from a first open end **514***a*″ over the axle **524**″ and between the axle **524**″ and the pin **522**″ and through a second opening **514***b*″. Then, when a user rotates the lever **518**″ in the advancing direction shown in FIG. **40**D, the tension line **523**″ is drawn into the device **500**″ through both openings **514***a*″ and **514***b*″ in the direction of the arrows.

[0202] FIGS. **41**A-**41**C show various side views of a one directional fit system, such as adjustment device **500**′, with a focus on a side view of a toroidal tensioning line channel **60** disposed therein. FIG. **41**A shows an outline view of the channel **60** in relationship to a hinged lever **62** and a housing **64**. FIG. **41**B shows a view similar to that of FIG. **41**A, but with radial dimension of the toroidal tensioning line channel **60** measured from an outer side of a spool axle **66** to an inner side of housing **64**. The radial dimension is a determinant of the length of tension line that can be wound on the axle **66** and stored in the toroidal tensioning line channel **60**. FIG. **41**C shows a view similar to those of FIGS. **41**A-**41**B, but with a focus on depicting the toroidal tensioning line channel **60** as a pseudo-solid for illustrative purpose, and further showing a single entry and exit pathway **68** of tensioning line into the channel **60**.

[0203] FIGS. **42**A-**42**C show embodiments of a toroidal tensioning line channel **70** within a dual-direction fit system, such as adjustment device **500**″. FIG. **42**A shows an outline view of the channel **70** in relationship to a hinged lever **72** and a housing **74**. FIG. **42**B shows a view similar to that of FIG. **42**A, but with radial dimension of the toroidal tensioning line channel **70** measured from an outer side of a spool axle **76** to an inner side of housing **74**. The radial dimension is a determinant of the length of tension line that can be wound on the axle and stored in the toroidal tensioning line channel **70**. FIG. **42**C shows a view similar to those of FIGS. **42**A-**42**B, but with a focus on depicting the toroidal tensioning line channel **70** as pseudo-solid for illustrative purpose, and further showing a dual entry and exit pathway **78***a*, **78***b* of tensioning line into the channel **70**.

[0204] FIGS. **43-52** show another adjustment device **600**, which includes a base **614** and cover **616** forming a housing, a spool **612**, a lever **618** coupled to the spool **612**, and a ratcheting advance and release mechanism **619** (FIG. **43**) coupled between the lever **618** and the spool **612** configured to drive (i.e., rotate) the spool **612** in a first rotational winding direction and to selectively permit the spool **612** to rotate in a second rotational unwinding direction opposite the first direction.

[0205] The base **614** and the cover **616** connect together, such as by snap fit or other fastening means. The base **614** includes a mounting flange **614***a* for mounting to an article, such as a wearable article. The flange **614***a* may be a stitch flange that can be attached to an article by sewing with needle and thread.

[0206] The cover **616** houses the spool **612** and portions of the ratcheting advance and release mechanism **619**. The spool **612** and ratcheting advance and release mechanism are coaxially aligned with a central longitudinal axis G-G around which the spool **612** rotates. A central axis H-H extends through the device **600** perpendicular to axis G-G. The spool **612** has opposing end flanges **612***a*, **612***b* with a plurality of circular grooves **612***c* formed along outer edges of the flanges **612***a*, **612***b*. The grooves **612***c* are spaced circumferentially apart, e.g., equidistantly.

[0207] The spool **612** is coupled to the ratcheting advance and release mechanism **619** as follows. Annular shaft couplers **650***a*, **650***b* are coaxial with the spool **612** and are connected to corresponding flanges **612***a*, **612***b* of the spool **612** with pins **652**. Specifically, coupler **650***a* defines grooves **650***al* that align with grooves **612***c* on first flange **612***a* of spool **612** and coupler **650***b* defines grooves **650***b***1** that align with grooves **612***c* on the second flange **612***b* of spool **612**. The grooves **612***c* are located on an outer edge of the flanges **612***a* and **612***b*, while the grooves **650***b***1** and **650***b***2** are located on an inner annular edge of the couplers **650***a*, **650***b* so that the flanges **612***a* and **612***b* are received into inner annular openings of the couplers **650***a*, **650***b*, as shown in FIG. **48**. The pins **652** rotationally fix the spool **612** to both couplers **650***a*, **650***b* so that the spool and the couplers **650***a*, **650***b* rotate in unison axis G-G.

[0208] Also housed within the inner annular openings of the couplers **650***a* and **650***b* are respective ratchet plates or wheels **654***a*, **654***b*, springs **656***a*, **656***b*, and spring caps **661***a*, **661***b*. The springs **656***a*, **656***b* urge the ratchet wheels **654***a*, **654***b* outward (with respect to central axis H-H) along axis G-G. Each coupler **650***a*, **650***b* has a radially inner (radially with respect to the central axis of G-G) cylindrical surface divided into an inner side and an outer side (with respect to central axis H-H). The outer side of the cylindrical surface has a plurality of inner gear teeth **650***a***3**, **650***b***3** while the inner side of the cylindrical surface is relatively smooth. Ratchet plate **654***a* includes pawls **654***a***1** that are oppositely directed from pawls **654***b***1** of ratchet plate **654***b*. The pawls **654***al* are configured to engage and drive the gear teeth **650***a***3** when the ratchet plate **654***a* rotates in the first rotational direction about axis G-G and to skip over the gear teeth when the ratchet plate **654***a* rotates in a second direction opposite the first direction. The pawls **654***b***1** are configured to skip over the gear teeth **650***b***3** when the ratchet plate **654***b* rotates in the first rotational direction about axis G-G and to engage with the gear teeth when the ratchet plate **654***b* is rotated in the second direction. This arrangement allows for a one-way spool winding of the spool **612**.

[0209] A keyed central shaft **660***a* extends coaxially through ratchet wheel **654***a*, spring **656***a*, and spring cap **661***a*, while a keyed central shaft **660***b* extends coaxially through ratchet wheel **654***b*, spring **656***b*, and spring cap **661***b*. The central shaft **660***a* rotates in unison with ratchet wheel **654***a* and spring cap **661***a*, which have a keyed central opening mating with the shaft **660***a*. The central shaft **660***b* rotates in unison with ratchet wheel **654***b* and spring cap **661***b*, which have a keyed central opening mating with the shaft **660***b*.

[0210] FIG. **48** shows the ratchet plates **654***a*, **654***b* in a first configuration in which they both ratchet plates **654***a*, **654***b* are engaged with respective gear teeth **650***a***3**, **650***b***3** on the outer side of the cylindrical surface of the couplers **650***a* and **650***b*. The ratchet plates **654***a*, **654***b* are longitudinally translatable along axis G-G from the outer sides to the inner sides of the cylindrical surface to disengage the pawls **654***a***1**, **654***b***1** from the respective gear teeth **650***a***3**, **650***b***3** in a second configuration. Disengagement of the ratchet plates **654***a*, **654***b* permits the spool to rotate freely in the second direction to unwind tension line. The longitudinal displacement of the ratchet plates **654***a*, **654***b* is selectively controlled by actuation of buttons **658***a*, **658***b*, further details of which are provided below. In a default position, the ratchet plates **654***a*, **654***b* are urged into the first configuration shown in FIG. **48**.

[0211] As shown in FIG. **48**, the ratchet plate **654***a* is coupled to the lever **618** by a gear **670** which is rotationally fixed to the central shaft **660***a*. The gear **670** is configured to be driven by the lever **618**. Thus, rotation of the gear **670** caused by the lever **618** can be transmitted to ratchet plate **654***a* through the central shaft **660***a*.

[0212] The lever **618** defines a hole **618***a* and a radially directed slot **618***b* extending from the hole on an inner side (relative to axis H-H) of the lever **618**. The hole **618***a* receives the gear **670** and the radial slot receives a spring **662** and a ball bearing **664** engaging the gear **670**. The base **614** includes a flange **614***b* defining an opening **614***b***1** in axial alignment with the longitudinal axis G-G. The flange **614***b* extends perpendicular to the lower surface **614***a* of the base **614**. The push button **658***a* extends outwardly (with respect to axis H-H) from and is retained in the opening **614***b***1** in the flange **614***b*. As shown in FIGS. **47** and **48**, the lever **618** is assembled between the flange **614***b* and the coupler **650***a*.

[0213] The gear **670** is longitudinally (along axis G-G) displaceable on central shaft **660***a* relative to the hole **618***a* in the lever **618**. As shown in FIG. **48**, the gear **670** is adjacent the ratchet plate **654***a*, which are both urged longitudinally outwardly against the push button **658***a* by the spring **656***a*. The push button **658***a* may be pushed inwardly against the force of the spring **656***a* to longitudinally translate the gear **670** and the ratchet plate **654***a* to disengage the pawls **654***al* of the ratchet plate **654***a* from the internal gear teeth **650***a***3** of the shaft coupler **650***a*. Release of the button **658***a* causes the spring **656***a* to expand to translate the ratchet plate **654***a* back to its engagement position where the pawls **654***al* engage with the gear teeth **650***a***3**.

[0214] The button **658***b* extends through a hole **616***b* of the cover **616**. The button **658***b* has a hexagonal profile and the hole **616***b* is hexagonal. The mating shapes prevents rotation of the button **658***b* in the hole **616***b*. The button **658***b* has a central opening that receives an end of shaft **660***b*. The button **658***b* is configured to be pushed inward (relative to axis H-H) along axis G-G, in opposition of the force of the spring **656***b*, to translate the ratchet plate **654***b* along axis G-G to disengage the pawls **654***b***1** from the teeth **650***b***3**. Release of the button **658***b*, causes the spring **656***b* to expand and translate the ratchet plate **654***b* back into engagement with the gear teeth **650***b***3**.

[0215] Thus, the release of the ratchet plates **654***a* and **654***b* is parallel with the longitudinal axis G-G. When both ratchet plates **654***a*, **654***b* are in their first, engaged configuration, rotation of the lever about axis G-G in a first direction will cause the ratchet plate **654***a* to drive the coupler **650***a* and the spool **612** connected thereto to rotate in unison with the coupler **650***a*, which will cause tension line to be drawn inward and gathered around the spool **612**. Also, when a user releases the lever **618**, the reverse orientation of the pawls **654***a***1**, **654***b***1** prevents the spool **612** from being unwound. However, when the ratchet plates **654***a*, **654***b* are in their second, disengaged configuration, by simultaneously pushing on both buttons **658***a* and **658***b*, the spool **612** is free to rotate in a reverse direction to permit the tension line to be reduced and the tension line to be unwound from the spool **612**.

[0216] The spring **662**, ball bearing **664**, and gear **670** comprise a tension limiting mechanism, shown in greater detail in FIGS. **51** and **52**. This mechanism limits the amount of tension in the tension line by limiting the amount of torque that can be applied to the gear **670** by the lever **618**. The gear **670** is driven by the lever **618** through the spring-biased ball bearing **664** that is mounted in the lever **618**. If the force input to the lever **618** is above a predetermined threshold, the force of the spring engagement onto the gear **670** will cause the ball bearing **664** to be pushed back (radially outward from the gear) against the force of the spring **662** and will thus skip teeth **670***a* on the gear **670**. This will cause the lever **618** to rotate about the axis G-G, while the gear **670** remains stationary relative to the base **614** and the cover **616**. However, if the force input to the lever **618** is below the predetermined threshold, the ball bearing **664** does not skip teeth **670***a* of the gear **670** and the lever **618** and the gear **670** will rotate about axis G-G in unison. The predetermined force limit depends on the stiffness of the spring **664**, which can be selected based on the intended application for the device **600**.

[0217] FIGS. **53-57** show an alternative adjustment device **700** similar to the adjustment device **600**. The adjustment device **700** differs mainly from adjustment device **600** in that adjustment device **700** includes an elongated spool **712** that is configured for winding tension lines that are flat straps rather than laces or cables that are used with spool **612**. In FIGS. **54-63**, like elements of adjustment device **600** are shown incremented by "100".

[0218] Device **700** has an elongated removable cover **716** with an elongated slot through which the tension line strap can pass to a split axle **724** of the spool **712**, shown in greater detail in FIG. **55**. As shown in FIG. **55**, the spool **712** corresponds to spool **612**, but includes an elongated slot **724***a* to receive and secure the tension line strap to the axle **724**. The device **700** includes push buttons **758***a* and **758***b* which are used to disengage the ratchet wheels **754***a* (FIG. **59**) and **754***b* (FIG. **56**), in the same way buttons **658***a* and **658***b* are used to disengage ratchet wheels **654***a* and **654***b*, to permit the spool **712** to freely rotate to unwind.

[0219] FIGS. **60-64** relate to an adjustment device **800** that includes a base **814**, a lever **818**, pivotally connected to the base **814**, and spool **812** pivotally connected to the base **814**. The spool **812** includes an axle **824** and two longitudinally spaced gears **806** fixed to the axle **824**. The gears **806** have rounded one-way slopping gear teeth with a coast side **806***a* and a drive side **806***b*. The axle **824** extends longitudinally along axis I-I (FIG. **62**). The axle **824** defines a longitudinal slot **824***c*, which is compressible about a tension line strap **823** to substantially secure the strap **823** to the axle **824** as shown in FIGS. **60** and **61**. A retaining pin **847** is shown and is utilized in this embodiment to retain the lever **818** around the gears **806**.

[0220] The device **800** includes a ratcheting strap advancement mechanism comprising a lever arm-mounted ratchet advancement tab **804** and a base-mounted tab **803**. The tabs **804** and **803** are configured to engage the gears **806** of the spool **812**. Both the lever arm tab **804** and the base mounted tab **803** are biased into the gears **806** such that the tabs (**803** and **804**) are pushed into the teeth of the gears **806** such that the tabs **803** and **804** block the gears from retraction when the adjustment device user wishes to wind the strap **823** under tension. The lever arm tab **804** is biased by a torsional spring **814** (FIG. **62**) and the base mounted tab **803** is biased by helical compression springs **813** (FIG. **62**). The springs **814** and **813** urge the tabs **804** and **803** radially inwardly (with respect to axis I-I) into engagement with the teeth of gears **806**.

[0221] As the lever **818** is rotated relative to the base **814** about axis I-I in a first direction (in FIG. **60**, gear rotation is in a clockwise direction although the rotation is in the counterclockwise direction when viewed from the other side of the device from that shown in FIG. **60**), the lever arm tab **804** catches the drive side **806***b* of the gears **806** and thereby rotates the gears **806** and axle **824** about the base **814** in the first direction. When the lever arm **818** is rotated in a second direction opposite the first direction (counterclockwise in FIG. **60**), the base mounted tab **803** engages the drive side **806***b* of the gears **806** and blocks the gears **806** from reversing rotational direction while the lever arm tab **804** skips over the coast side **806***a* of the gears **806**, which has a gradual slope that pushes the lever arm tab **804** away from the gear **806** against the force of the spring **814** until the tab **804** passes the gear tooth and clicks down into the space between the gear teeth. A repeating clicking noise occurs as the lever arm tab **804** skips over the teeth of the gears **808** as the lever **818** rotates about the base **814** in the second direction.

[0222] The adjustment device **800** provides significant mechanical advantage for the user to wind the tension line strap **823** in applications where the device **800** is coupled to a wearable article or otherwise used to fit about the body of a human or animal. The mechanical advantage of this device is provided, in part, by the length of the lever **818**, which, in the illustrated embodiment, is approximately 33 mm long and is approximately 26 mm from the end of the lever **818** to the center of the axle **824**. The lever **818** could be made longer to provide more mechanical advantage, but the overall profile and bulk of the adjustment device **800** would also increase as well. Moreover, a longer lever **808** may increase the chance for inadvertent rotation of the lever **818** and winding of the strap **823**. Furthermore, without being bound by theory, it is believed that that the length of the lever **818** in combination with the base **814**, gears **808**, and gear teeth (in terms of teeth size and number of teeth) is preferred for applications fitting to the body wherein a human user can create a suitable amount of tension and resulting load in the tension line **823**, but not an excessive amount that could be detrimental to circulation or otherwise inappropriate.

[0223] The device **800** includes a mounting mechanism for the base **814** wherein the base can be fastened to an article. As shown in FIG. **60** the base **814** defines a plurality of countersunk holes

825 which are designed to receive fasteners (not shown) for fastening the base **814** to an article. The fasteners are designed to be accessible for assembly by advancing the lever arm **818**, but to be concealed (as in FIG. **60**) under the lever arm **818** for visual simplicity.

[0224] The adjustment device **800** also includes a collection funnel mechanism which is shown as rounded edges **826** (FIG. **60**) where the tension line strap **823** enters and exits the base **814**. The rounded edges **826** aid in collecting and organizing the strap **823** as it is drawn toward and around the collecting axle **824** or is released from it. Furthermore, the rounded edges **826** help to reduce abrasion of the strap **823** by the base **814** during use.

[0225] The device **800** includes a release mechanism that allows the user to quickly and easily simultaneously release both the lever arm tab **804** and the base mounted tab **803** from the spool **812** with one hand. The release mechanism of device **800** can be better viewed from the top and is demonstrated in further detail in FIGS. **62-64**. FIG. **62** shows release buttons **840** and helical compression springs **842** for the release buttons **840** on opposite sides of the base **814**. The release buttons **840** and springs **842** are coaxial with the axle **824**. The springs **842** bias the release buttons **840** back away from the lever arm tab **804** and away from the base mounted tab **803**. Each release button **840** has a circumferential tab **828** with a tapered cam surface **876** that engages the tabs **804** and **803**. The base **814** includes retention tabs **814***a* that abuts the outer sides of the release buttons **840** to retain the release buttons **840**.

[0226] FIG. **62** show a detailed view of one of the release buttons **840** in a first position where the buttons **840** are in contact with the retention tabs **814***a*. FIG. **64** demonstrates how the base mounted tab **803** and the lever arm tab **804** can be simultaneously disengaged from the gears **806** by pushing both release buttons **840** in the direction of the arrows along axis I-I. As the buttons **840** are pushed in, the tapered cam surface **876** of the circumferential tabs **828** slide against edges of the tabs **803** and **804** to spread the tabs **803** and **804** outwardly along an axis J-J perpendicular to axis I-I in the direction of arrows.

[0227] The device **800** also provides a lower profile solution than the split axis and manual feeding strap axis solution presented in the prior art. In this embodiment, the axle **824** is fabricated as two separate halves that are assembled together when coupled with the gears **808** on both sides of the axle **824**. When the two halves of the axle **824** are joined together and coupled with a gear **808** on each side, a strap **823** with melted or otherwise expanded end (such as including a small retention pin at the end of the strap) is placed between the halves of the axle **824**. The strap **824** is thereby pinched in between the halves of the axle **824** and retained. This arrangement would also allow for the gear to be on the outside of the lever **818** and base **814**.

[0228] The release mechanism and method described herein allows a user to quickly and easily release both the lever arm tab **804** and the base mounted tab **803** simultaneously with one hand, which thereby allows the spool **812** to unwind partially or fully, if desired. The method to release the strap in the prior art included the need to use two hands in a multi-step process that also required a separate tab release. In order to release adjustment device **800**, the user need only press both release button **840** at the same time with one hand, by way of the ergonomic and strong pinch motion that humans can easily do with one hand, for example, with their thumb and index finger. The use of a two-finger or two-button release using a pinching motion release also helps to avoid unintentional release of the system.

[0229] It is also notable that the release buttons **840** can be pushed to release the spool **812** when the lever **818** is in any rotational position relative to the base **814**. This ability for the user to release the tension line **823** from any position in an ergonomic way and with ease while also offering a mechanism that is unlikely to inadvertently release provides distinct advantages over the prior art for devices and garments fitting the body.

[0230] Turning back to the side view of the device **800** shown in FIG. **60**, the lever **818** is shown in a first rest position in a recessed location at one end **814***b* of the base **814**. It will be appreciated that due to the shape of the base **814**, the lever **818** may also be recessed when rotated in position at a second end **814***c* of the base **814**, thereby offering a reversible device and the ability for the user to rest the lever **818** in whatever position is best for the user and the particular application.

[0231] The device **800** has a tension line collection volume defined between the base **814** and the axle **824**. The collection volume is used to store the tension line **823** as the axle **824** winds the tension line **823**. The device **800** also includes a lever arm safety catch and release mechanism **874** (FIG. **60**), which in this embodiment includes a leaf spring with barbed feature to catch on the matching mechanical catch **853** set in the base **814**.

[0232] FIG. **65** shows a partially transparent (right side) view of an embodiment of an adjustment device **900** having a release mechanism configured with a front side pull release. Other than the alternative release mechanism, the FIGS. **65-68** use the same adjustment mechanism as the single adjustment embodiment shown in FIGS. **39**A-**39**B. However, the same release mechanism that is highlighted in device **900**, is also applicable to the dual adjustment mechanism of FIGS. **40**A to **40**D. For ease of illustration and by way of example, FIGS. **65-68** refer to features of device **500′**

[0233] FIG. **65** shows ratchet pawl **550′** pivotally connected to the base **514′** at A to creating a one-way rotation degree of freedom between the base **514′** and the axle **524′**. The pawl **550′** shown has a lever arm extending from A to a second pivotal connection at B. The pawl **550′** is pivotally connected to a release cable **902** at B. The cable **902** includes an ergonomic handle **904** or catch for hand or hook single action pull release. The cable transfers pull force to the pawl **550′** by way of a tunnel **906** through the base **514′**. If the release cable **902** is pulled to the front (in the direction of arrow) via handle **904**, it will cause the pawl **550′** to rotate about B and A to disengage the pawl **550′** from the ratchet gear **513′**. It will be appreciated that the handle **904** transmits a force in a direction of the arrows shown in FIG. **65**. This force can also be imparted to the pawl **550′** at B if the force was imparted on a side of the housing opposite the handle **904**.

[0234] FIG. **66** shows an opposite side of the device **900** shown in FIG. **65**. Specifically, FIG. **66** shows ratchet pawl **540′** pivotally connected to lever **518′** at C. The pawl **540′** is also pivotally connected to the release cable **902** at D. The cable **902** must move with the rotation of the lever **518′** during winding and retraction of the lever **518′**. This movement of the cable **902** is accommodated by routing the cable path from the handle **904** to D near the axis (F-F) of rotation of the lever **518′** such that the cable **902** does not need to move excessively to accommodate the motion of the lever **518′**. If the release cable **902** is pulled to the front (in the direction of the arrow) via handle **904**, it will cause the pawl **540′** to rotate about D and C to disengage the pawl **540′** from the driven gear **510′**.

[0235] FIG. **67** shows a transparent top view of the device **900** shown in FIG. **65**. FIG. **68** shows the motion (a pulling hand gesture) that a user of the device would take to release the spool **512′**. FIG. **67** shows that as the handle **904** is pulled forward in the direction of the arrow **910**, the cables **902** on both sides of the spool **512′** release both pawls **540′** and **550′** simultaneously, thereby allowing the axle **524′** to spin independently from the base **514′** and the lever **518′**. With tension in the tension line strap **523′** the release of the spool **512′** will thus naturally cause the tension line strap **523′** to unwind out of the spool **512′**. The arrows **910** in FIG. **68** show application of the required release force to the handle **904**. Arrows **912** show the direction of extension of the tension line **523′** in a single adjustment embodiment, whereas arrows **912** and **914** show the direction of extension of the tension line **523′** in a dual adjustment embodiment.

[0236] FIGS. **69-72** show embodiments of an adjustment device **1000** with a single-action, back-side pull release. FIGS. **69-72** refer to features of the device **500′**. FIGS. **69-72** show an embodiment of an adjustment device **1000** having a release mechanism that includes a back-side pull release cable **1002** and a handle **1004**. The release cable **902** is routed from the back around approximately 180 degrees to B on pawl **550′** and to D on pawl **540′**. Thus, the cable routing transmits rearward force on the handle **1004** to forward directed force acting on the pawls **550′** and **540′**. FIG. **71** shows a transparent top view of the device embodiment shown in FIGS. **69-70**. In view of the routing of the release cable **1002** to the pawls **550′** and **540′** shown in FIG. **76**, both pawls **550**′ and **540**′ are configured to simultaneously disengage from the gears **513**′ and **510**′.

[0237] FIG. **72** shows a top view of the device **1000** and demonstrates the hand motion that a user would take to release the device **1000**, by pulling the handle **1004** in the direction of arrows **1010**. The strap or cable **523**′ would then release out of the spool **512**′ as described above if there is tension in the system, which is depicted by the arrows on the strap in FIG. **72**. The arrows **1010** in FIG. **72** show application of the required release force to the handle **1004**. Arrows **1012** show the direction of extension of the tension line **523**′ in a single adjustment embodiment, whereas arrows **1012** and **1014** show the direction of extension of the tension line **523**′ in a dual adjustment embodiment.

[0238] FIGS. **73-76** show an adjustment device **1100** having release cables **1102**, **1103** connected between a rotatable knob **1104** and pawls **540**′ and **550**′ to transfer pull force to simultaneously pull the pawls out of engagement with mating gears **510**′ and **513**′ in a single action by rotating the knob **1104** (e.g., counterclockwise in these examples).

[0239] FIG. **73** shows pawl **550**′ pivotally connected to the base **514**′ at A and to cable **1102** at B. The cable **1102** is routed rearward over and around axle **524**′ approximately 180 degrees to rotatable knob **1104**. FIG. **74** shows pawl **540**′ pivotally connected to lever **518**′ at C and to cable **1103** at D. The cable **1103** is routed rearward over and around axle **524**′ approximately 180 degrees to rotatable knob **1104**.

[0240] FIG. **75** shows a partially transparent top view of the device **1100** in a neutral state where the pawls **540**′ and **550**′ are fully engaged with the gears **510**′ and **513**′, respectively. The knob **1104** defines internal pathways for routing cable **1102** to pivot E and for routing cable **1103** to pivot F. The internal pathways increase leverage on the cables **1103** and **1102** when the knob **1104** rotates in the direction of arrow A in FIG. **80**. If the knob **1104** is rotated in the direction of arrow **1110**, both tension lines **1102** and **1103** will pull in the same direction (e.g., to the right in FIG. **80**) simultaneously, thereby pulling on and disengaging the pawls **540**′ and **550**′ at the same time.

[0241] FIG. **76** shows a method of releasing the device **1100** by way of rotating the knob **1104** using one finger. The arrow **1110** in FIG. **76** shows application of the required release force to the knob **1104**. Arrows **1112** show the direction of extension of the tension line **523**′ in a single adjustment embodiment, whereas arrows **1112** and **1114** show the direction of extension of the tension line **523**′ in a dual adjustment embodiment.

[0242] FIGS. **77-80** show an embodiment of an adjustment device **1200** having release lines **1202** and **1203**, connected between a lever **518**′ and pawls **540**′ and **550**′, that transfer tension to pull pawls **540**′ and **550**′ out of engagement with gears **510**′ and **513**′, respectively.

[0243] FIG. **77** shows pawl **550**′ pivotally connected to base **514**′ at A and to cable **1202** at B. The cable **1202** is routed rearward over and around axle **524**′ approximately 180 degrees to rotatable lever **1204**. FIG. **78** shows pawl **540**′ pivotally connected to lever **518**′ at C and to cable **1203** at D. The cable **1203** is routed rearward over and around axle **524**′ approximately 180 degrees to rotatable lever **1204**.

[0244] FIG. **79** shows a partially transparent top view of the device **1200** in a neutral state where the pawls **540**′ and **550**′ are fully engaged with the gears **510**′ and **513**′, respectively. The lever **1204** defines internal pathways for routing cable **1202** to pivot E and for routing cable **1203** to pivot F. The internal pathways increase leverage on the cables **1203** and **1202** when the lever **1204** rotates in the direction of the arrow in FIG. **79**. If the lever **1204** is rotated in the direction of the arrow **1210**, both tension lines **1202** and **1203** will pull in the same direction (e.g., to the right in FIG. **79**) simultaneously, thereby pulling on and simultaneously disengaging the pawls **540**′ and **550**′.

[0245] FIG. **80** shows a method of releasing the device **1200** by way of rotating the lever **1204** using one finger. The arrow **1210** in FIG. **80** shows application of the required release force to the lever **1204**. Arrows **1212** show the direction of extension of the tension line **523**′ in a single adjustment embodiment, whereas arrows **1212** and **1214** show the direction of extension of the tension line **523**′ in a dual adjustment embodiment.

[0246] FIG. **81**A shows a fit system **1301** that includes an adjustment device **1300**, a tension line **1323**, and a pressure distribution pad **1333** that can be positioned below the adjustment device **1300**, interfacing between the adjustment device **1300** and a surface, which may be a curved surface such as a surface of a human or animal body or an article conforming to a human or animal body surface. As shown in FIG. **81**C, the pressure distribution pad **1333** may be curved a curved to correspond more closely with the curvature of a surface to which the pad is mounted.
[0247] Pressure distribution of the fit system may relate to the load delivered, surface area, geometry or shape of the fit system, and/or rigidity of fit system components. The amount of load onto the body applied by a fit system divided by the surface area of the applied load will yield a given pressure distribution. For most applications that require a high-tension fit system (tension over 100 lbs.), it is recommended that associated loads be distributed onto straps over 1.5″ in width or which have a surface area of at least 8 square inches. For example, a fit system that is low in profile and includes a contour that matches the body it is applied to, has tapered rigidity of its members wherein the system becomes less rigid near the edges, and has rounded edges. One important aspect of the fit system shape is how well the contour of the pressure distribution pad **1333** matches the natural curvatures of the body or how well it can conform to that shape such that pressure can be evenly distributed over the body. Another important aspect of the shape is how sharp or blunt (the radius) the edges are of the fit system members. Edges that are too sharp can lead to peak pressures that could result in discomfort, bruising, or skin abrasion.
[0248] By way of example, FIGS. **82** and **83** show the adjustment device **1300** and pressure distribution pad **1333** banded about a user's leg with the adjustment device **1300** and pad **1333** positioned on the front of the leg. Also, as shown in FIG. **82**, an additional pressure distribution pad **1334** is located on the back side of the leg between a strap **1302** and the leg to distribute pressure to the leg. In addition, pressure distribution pads **1336***a* and **1336***b* are located on the inner and outer sides of the leg, respectively. The pads **1334**, **1336***a*, and **13366***b* may be relatively low in durometer. Pressure distribution pads **1336***a* and **1336***b* have a low durometer inner surface and a semi-rigid shell that define a channel for strap **1302** to pass between the inner and outer surfaces (inner and outer being relative to outer surface of the leg) of the pads **1336***a*, **1336***b*. In the embodiment shown in FIGS. **82** and **83**, strap tension is not distributed directly onto the body (e.g., the leg). Instead, strap tension and resulting forces from strap tension are distributed indirectly through pressure distribution pads **1334**, **1336***a*, and **1336***b*. As force equals pressure divided by area, resultant forces of this fit system are reduced by increasing the surface area of pressure distribution. As shown in FIG. **84**, the pressure distribution pads **1333** and **1334** cause the tensile forces in the strap **1302** to direct compressive forces in the direction of the arrows in FIG. **84**.
[0249] In FIG. **85** the location of the adjustment device **1300** and pressure distribution pad **1333** is shifted to a more curved portion of the leg. In the embodiment shown in FIG. **85**, the pressure distribution pad **1333** is flexible and therefore bends to match the curvature of the leg. The ability for many of the adjustment devices herein to slide along the length of the tension line (e.g., strap) while the tension is loose can be made possible by fixing the tension line on either side of the tension line and passing the tension line continuously through the spool of the adjustment device. Such embodiments can permit selective placement of the adjustment device (as shown in FIGS. **84** and **85**) for device adjustment in order to maximize comfort and/or improve performance or convenience.
[0250] FIGS. **86-88** show details of a collection feeder **1335** shown in FIG. **81**A. This particular embodiment is shown with a tensioning line **1302** in the form of a strap, but it could also be applicable to a tensioning line in the form of a cable.
[0251] FIG. **86** shows a transparent side view of a tensioning line collection guide or funnel **1335** for the adjustment device **1300**. Collection guide **1335** guides the tension line **1302** into and out of the housing of the adjustment device **1300**. As shown in FIG. **99**, the guide or funnel **1335** has a flared outer opening. Also, as shown in FIG. **87**, the collection funnel **1335** is flexible and can bend

in response to forces applied by the tension line **1302**.

[0252] Inherently, all articles or devices that fit to the body are subjected to the forces of gravity. Suspension forces are forces generated by a fit system to counteract the forces of gravity and suspend the device onto the body. The weight of a fit system itself will contribute to the overall weight of the device and therefore lighter weight fit systems are preferable. The various embodiments of fit systems described herein may be made lighter by removing material and adding cutouts. For example, the embodiment of an adjustment device **1400** shown in FIG. **89** features material cutouts **1402** to remove material for the purpose of reducing the weight of the device **1400**.

[0253] Various modifications can be made to the levers of the fit systems described herein. For example, as shown in FIG. **90**, a fabric or cable pull strap **1502** can be attached to a lever **1518** of an adjustment device **1500** and used as a pull by a user to actuate the lever **1518** back and forth in the direction of the arrows.

[0254] Also, as shown in FIGS. **91** and **92**, the levers **1618** may be formed as sectional parts that can be connected to extend the length of the lever **11**. In FIG. **91**, an adjustment device **1600** has a lever that has two portions **1618***a* and **1618***b* connected by a hinge **1618***c*. In FIG. **104** portion **1618***b* is shown folded back on portion **1618***a* to conserve space when the lever **1618** is not being used. As shown in FIG. **92**, the portion **1618***b* can be rotated about hinge **1618***c* to fully extend the length of the lever **1618** to provide the user with increased leverage for winding the spool.

[0255] In another embodiment, an adjustment device **1700** (FIGS. **93** and **94**) has a lever **1718** with a mount configured to mount an extension bar **1702** to increase leverage of the lever **1718**. In the embodiment shown, the lever **1718** defines a receptacle opening into which one end of the bar can be inserted, as shown in FIG. **94**. The bar **1702** may be stored separately from the device **1700** when not being used for adjusting adjustment device **1700**.

[0256] FIGS. **95** and **96** show an embodiment of an adjustment device **1800** with an integrated quick catch **1854** that is configured to releasably connect to a mating latch **1858** which includes a quick release mechanism **1856**. In this embodiment there is an opposing strap **1850** connected to the latch **1858**. In other embodiments, the latch **1858** could be connected directly to a device fitting the body of the user or other member. In FIG. **95**, the catch **1854** is detached from the latch **1858** and as such allows for easy donning and doffing and to be applied to products that require a full opening of one or more portions of the device. This figure is shown at a 1:1 scale.

[0257] FIG. **96** shows the catch **1854** connected to the latch **1854**. The quick release mechanism **1856** includes a quick release push-up tab **1862**, which is configured to pushes the base side of quick connect **1854** to release from the latch **1858** when a release button **1840** is depressed. Specifically, the tab **1862** is pivotally connected to the latch **1858** at pivot **1860** so that when the button **1840** is depressed, the button **1840** pushes a first end **1862***a* of the tab **1862** down to raise a second opposed end **1862***b* of the tab **1862**. The movement of the second end **1862** of the tab **1862** opens the quick connect **1854** to release it form the latch **1858**. The catch **1854** and latch **1858** may include magnetics to guide their connection.

[0258] FIG. **97** shows a side view of an adjustment device **1900** in accordance with an aspect of the disclosure. The fits device **1900** includes an integrated quick catch **1955** that is configured to connect to a mating catch **1967**. Wherein the catch **1955** is formed as a hook with a barreled end **1964**, mating surface **1966**, and a south pole magnet **1980** for magnetic connection. The opposing catch **1967** has complementary and mating features to those of the catch **1955**, including a barreled end **1963**, mating surface **1966**, and a north pole magnet **1970** for magnetic connection. The catch **1967** also includes a nesting surface **1968** that matches a curvature **1969** of a base **1914** of the adjustment device **1900**. In FIG. **97**, the catches **1955** and **1967** are disconnected, which may be necessary to don a device or to retract the fit device base to the approximate length necessary, then use the lever arm and mechanism to apply the desired load onto the body.

[0259] FIG. **98** shows the adjustment device **1900** connected to the catch **1967**. Specifically, quick catch **1955** and catch **1967** are joined together. The catches **1955** and **1967** come together more easily and are aligned by the magnets **1980** and **1970**. In this embodiment, the catches **1955** and **1967** are shifted perpendicular to the catching mechanism (i.e., into or out of the page in FIG. **111**) to release the two catches **1955** and **1967** from one another. Since this motion of the catches **1955** and **1967** imposes a sheer force on the magnets **1980** and **1970**, the force of the magnets is easily overcome by the user and yet is strong enough to avoid inadvertent disconnection.

[0260] In FIGS. **99***b***-122** show various uses of adjustment devices in fit systems and line tensioning systems. In describing the various systems **120** (fit systems and line tensioning systems) shown in FIGS. **99***b***-122**, reference will be made to an adjustment device thereof, which can be any of the adjustment devices described herein in accordance with this disclosure. It will be appreciated that adjustment device **120** may take the form of any of the embodiments of an adjustment device described herein and is not limited to the schematics shown in FIGS. **99***b***-122**.

[0261] FIG. **99***a* shows a side view of a human profile wherein the body has been fit with various devices or garments that include ratchet strap systems **110** and a rotary dial adjustment device **111** of the prior art. By way of comparison to the prior art systems **110** and **111** shown in FIG. **99***a*, the systems **120** in accordance with an aspect of the disclosure shown in FIG. **99***b* have a lower profile. The larger profile of the prior art systems **110** and **111** are bulkier and can cause increased impact force on the portion of the body attached to the systems **110** and **111** if a user falls or is impact in that area of the user's body.

[0262] FIGS. **100-108**, and **111-122** show fit systems **120** connected to wearable articles. FIG. **100** shows a fit system **120** connected to a helmet and used as helmet strap. The adjustment device of the fit system may be mounted to the shell of the helmet or may be left free to be positioned along the strap at an intermediate position between the sides of the helmet.

[0263] FIG. **101** shows multiple fit systems **120** connected to a ski boot. The straps are banded around a leg portion and a foot portion of the boot and the adjustment devices of the straps may be mounted directly to the leg and foot portions of the boot. FIG. **102** shows fit systems **120** connected to snowboard boots. Straps of the systems are banded about the leg portion of the snowboard boots with the adjustment device mounted directly to the boot. Also, straps of the fit system **120** are shown connected to the snowboard and include adjustment devices mounted to the snowboard straps which can be used to adjust the connection of the snowboard boots to the snowboard.

[0264] FIG. **103** shows a fit system **120** connected to a skate, specifically an ice skate. The adjustment device of the fit system is mounted directly to the skate while the tension line is banded about the skate. FIG. **104** shows an embodiment of a fit system **120** connected to a sandal. The adjustment device of the fits system is mounted to one of the sandal straps while the tension line takes the place of a sandal closure strap. FIG. **105** shows a fit system **120** connected to a shoe. The adjustment device of the system is mounted to the shoe and the strap extends across the tongue of the shoe. FIG. **106** shows a fit system **120** connected to a boot, where the fit system is arranged identically to the system shown in FIG. **103** used with a skate.

[0265] FIG. **107** shows an embodiment of a fit system **120** used for an adjustable strap of a day pack application. The tension line of the system **120** is connected to the day pack and the adjustment device is not directly mounted to the day pack but is spaced therefrom. FIG. **108** shows a fit system **120** used for an adjustable strap of a bag or backpack (e.g., a camping backpack). The tension line of the system **120** is connected to the backpack and the adjustment device is not directly mounted to the backpack but is spaced therefrom.

[0266] FIGS. **111-115** show fit systems **120** applied to protectable wearable articles utilized in the field of motorsports. Specifically, FIG. **111** shows fit systems **120** applied to a protective vest that can be used to adjust the fit of the vest to a user. FIG. **112** shows fit systems **120** applied to a protective suit. The fit systems can be used to adjust the fit of the protective suit to a user's body at the locations shown in FIG. **112**. FIG. **113** shows a fit system **120** applied to a motorcycle boot. As shown in FIG. **113**, two straps are banded about the boot: one strap banded about a leg portion of the boot and one strap banded about the foot. Separate adjustment devices may be provided for each strap to independently tension each strap. FIG. **114** shows fit systems **120** applied to protective knee pads where the strap is configured to be banded about the knee of a user and the adjustment device is can be used to adjust the fit of the straps. FIG. **115** shows a fit system **120** applied to protective pants for adjusting the waist of the pants to fit a waist of a user.

[0267] FIGS. **121** and **122** show fit systems **120** utilized in the field of clothing accessories and clothing. As shown in FIG. **121**, the fit system **120** is used as a belt for a pair of pants, which may be integrated into the pants. For example, the adjustment device may be mounted to the pants with the strap of the fit system **120** banded about the waist of the pants. FIG. **122** shows the fit system **120** in the form of a belt. Where the fit system **120** is worn about the body, it is preferred to incorporate a tension limiter. However, in certain applications where the fit system **120** is intended to apply tension around the body, such as a tourniquet, it will be appreciated that the tension device of the fit system **120** would omit a tension limiter.

[0268] FIGS. **116-120** show various uses of the fits systems **120** in the field of orthopedics. FIG. **116** shows a fit system **120** utilized in the field of orthopedics applied to an ankle brace or ankle orthosis. As shown in FIG. **116** one strap is banded about a leg portion of the brace and one strap is banded about a foot portion of the brace. The adjustment device of the fit system **120** is mounted to the device and controls tension in the two straps. FIG. **117** shows fit systems **120** applied to a prosthetic socket. For the socket, adjustment devices are connected to the socket at various locations and are connected by tension lines. Applying or relieving tension in the tension lines can enlarge or reduce the opening of the prosthetic to adjust the fit of the prosthetic to a user. FIG. **118** shows a fit system **120** applied to a back brace or thoracic lumbar sacral orthosis (TLSO) application. The strap of the system **120** is banded about the back and torso of the user and the adjustment device is positioned over a user's chest for access to the user. FIG. **119** shows fit systems **120** applied to a knee brace or knee orthosis. One fit system is banded about the leg above the knee, while another fit system is banded about the leg below the knee. The adjustment devices of the fit systems **120** can adjust tension in the straps to fit the straps to the user's leg. FIG. **120** shows fit systems **120** applied to a post-operative knee brace or knee immobilizer. The fit systems are shown banded about the user's lower leg.

[0269] FIGS. **109** and **110** show uses of line tensioning systems **120**. FIG. **109** shows fit systems **120** used as straps of a suspended tent. Each strap is connected to a corresponding adjustment device. Each strap is configured to connect at one end to a tent and an opposite end to another structure (such as a tree) to suspend the tent above the ground. The line tensioning systems may also be used for other suspensions applications, such as mountaineering, rock-climbing, and rappelling. Similarly, the line tensioning system may be used to tension sporting nets, such as for tennis, badminton, volleyball, table tennis, etc., and may be provided with the equipment therefor. FIG. **110** shows line tensioning systems **120** used as cargo tie down straps connected to a truck bed. The line tensioning systems described herein can also be used as closures in carry-alls, suitcases, duffel bags, sport bags, and thus may be incorporated into such articles in accord with the intended scope herein.

[0270] There have been described and illustrated herein several embodiments of a tension device, fit systems using the tension device, and a method of using the tension devices and fit systems. While particular embodiments of the invention have been described, it is not intended that the invention be limited thereto, as it is intended that the invention be as broad in scope as the art will allow and that the specification be read likewise. Thus, while particular tension line types have been disclosed, it will be appreciated that other tension line types may be used as well. For all of the embodiments, the line tensioning systems may be made from a plastic, metal, or a combination plastic and metal components. In addition, while particular types of plastics have been disclosed for parts of the embodiments, it will be understood that other suitable types of plastics can be used. For example, and not by way of limitation, acrylic and polycarbonate may be used. Moreover, while particular configurations have been disclosed in reference to housings for the tension devices, it will be appreciated that other configurations could be used as well. It will therefore be appreciated by those skilled in the art that yet other modifications could be made to the provided invention without deviating from its spirit and scope as claimed.

Claims

1. An adjustment device for use with at least one tension line, the adjustment device comprising: a rotatable spool operably coupled to the at least one tension line, the spool configured to rotate about a first axis in a first rotational direction to wind the at least one tension line around the spool, and wherein the spool is further configured to rotate about the first axis in a second rotational direction opposite the first rotational direction to unwind the at least one tension line from the spool, the spool provided with a driven gear having a first set of teeth arranged coaxially about the first axis; a drive gear coupled to the driven gear, the drive gear having a second set of teeth arranged coaxially about the first axis; a lever component selectively coupled to the driven gear to drive rotation of the spool in the first rotational direction; and a release mechanism that is configured to selectively release the spool such that the spool is free to rotate in either the first rotational direction or the second rotational direction in response to manual forces applied to the release mechanism.
2. The adjustment device according to claim 1, wherein the lever component is pivotally coupled relative to the drive gear.
3. The adjustment device according to claim 1, wherein the lever component is configured to rotate about the first axis.
4. The adjustment device according to claim 1, wherein the release mechanism decouples the drive gear from the driven gear.
5. The adjustment device according to claim 1, wherein the release mechanism decouples the drive gear from the spool.
6. The adjustment device according to claim 1, wherein the release mechanism decouples the lever component from the driven gear.
7. The adjustment device according to claim 1, wherein the release mechanism decouples the lever component from the spool.
8. The adjustment device according to claim 1, wherein the release mechanism is operated by applying a force parallel to the first axis.
9. The adjustment device according to claim 8, wherein the release mechanism is operated by applying the force to the lever component.
10. The adjustment device according to claim 8, wherein the release mechanism is operated by applying the force and an opposite force parallel to the first axis.
11. The adjustment device according to claim 1, further comprising a housing extending over the spool and drive gear.
12. An adjustment device for use with at least one tension line, the adjustment device comprising: a rotatable spool operably coupled to the at least one tension line, the spool configured to rotate about a first axis in a first rotational direction to wind the at least one tension line around the spool, and wherein the spool is further configured to rotate about the first axis in a second rotational direction opposite the first rotational direction to unwind the at least one tension line from the spool, a drive gear coupled to the spool, the drive gear having a second set of teeth, each having a height extending in a direction perpendicular to a direction of a tension on the at least one tension line; a lever component pivotal relative to the spool and configured to rotate on the first axis, the lever component selectively coupled to the spool to drive rotation of the spool in the first rotational direction; and a release mechanism that is configured to selectively release the spool such that the spool is free to rotate in either the first rotational direction or the second rotational direction in

response to manual forces applied to the release mechanism.

13. The adjustment device according to claim 12, wherein the lever component is pivotally coupled relative to the drive gear.

14. The adjustment device according to claim 12, wherein the lever component is configured to rotate about the first axis.

15. The adjustment device according to claim 12, wherein the spool is provided with a driven gear having a second set of teeth engaged by the first set of teeth.

16. The adjustment device according to claim 15, wherein the release mechanism decouples the drive gear from the driven gear.

17. The adjustment device according to claim 15, wherein the release mechanism decouples the lever component from the driven gear.

18. The adjustment device according to claim 12, wherein the release mechanism decouples the drive gear from the spool.

19. The adjustment device according to claim 12, wherein the release mechanism decouples the lever component from the spool.

20. The adjustment device according to claim 12, wherein the release mechanism is operated by applying a force to the parallel to the first axis.

21. The adjustment device according to claim 20, wherein the release mechanism is operated by applying the force to the lever component.

22. The adjustment device according to claim 20, wherein the release mechanism is operated by applying the force and an opposite force parallel to the first axis.

23. The adjustment device according to claim 12, wherein the release mechanism is operated by applying a force to the lever component.
