US009365387B2

(12) **United States Patent**
Beers et al.

(10) **Patent No.: US 9,365,387 B2**
(45) **Date of Patent: Jun. 14, 2016**

(54) **MOTORIZED TENSIONING SYSTEM WITH SENSORS**

(71) Applicant: **Nike, Inc.**, Beaverton, OR (US)

(72) Inventors: **Tiffany A. Beers**, Portland, OR (US); **Andrew A. Owings**, Portland, OR (US); **Cody Collier Henderson**, Denver, CO (US); **James Alan Capra**, Steamboat Springs, CO (US); **Mark Stanley Soderberg**, Conifer, CO (US); **Daniel Hipwood**, Denver, CO (US)

(73) Assignee: **NIKE, Inc.**, Beaverton, OR (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 24 days.

(21) Appl. No.: **14/014,555**

(22) Filed: **Aug. 30, 2013**

(65) **Prior Publication Data**

US 2014/0070042 A1 Mar. 13, 2014

Related U.S. Application Data

(60) Provisional application No. 61/695,953, filed on Aug. 31, 2012.

(51) **Int. Cl.**

B65H 59/38	(2006.01)
A43C 11/00	(2006.01)
A43C 11/16	(2006.01)
A43B 3/00	(2006.01)
A61F 5/02	(2006.01)
B65H 59/00	(2006.01)
A43B 11/00	(2006.01)

(52) **U.S. Cl.**

CPC ***B65H 59/384*** (2013.01); ***A43B 3/0005*** (2013.01); ***A43B 3/0015*** (2013.01); ***A43B 11/00*** (2013.01); ***A43C 11/00*** (2013.01); ***A43C 11/008*** (2013.01); ***A43C 11/165*** (2013.01); ***A61F 5/028*** (2013.01); ***B65H 59/00*** (2013.01)

(58) **Field of Classification Search**

CPC A43B 11/00; A43B 11/165
USPC 36/50.1, 137
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,702,583 A 2/1929 Williams
1,916,483 A 7/1933 Krichbaum

(Continued)

FOREIGN PATENT DOCUMENTS

DE 298 17 003 U1 3/1999
DE 198 33 801 A1 2/2000

(Continued)

OTHER PUBLICATIONS

Blake Bevin, Power Laces Prototype Version 1, Uploaded Jul. 4, 2010 http://www.youtube.com/watch?v=ROEZsOHpFQc&feature=endscreen&NR=1.
Blake Bevin, Power Laces Prototype Version 2, Uploaded Aug. 29, 2010 http://www.youtube.com/watch?v=k_Efr2TaEPo.
Blake Bevin, Power-Laces.com Archived, About the Project, Aug. 18, 2012.

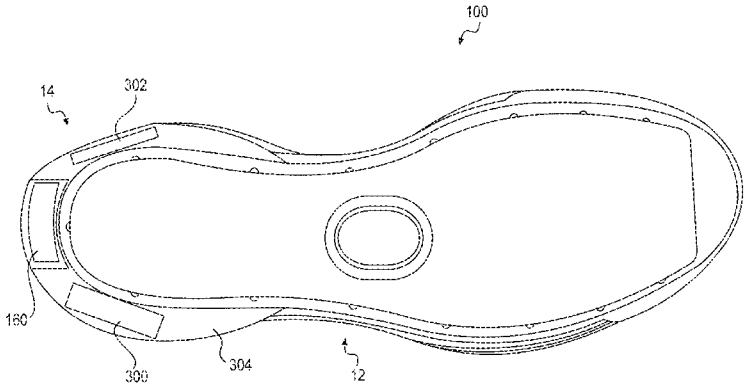
(Continued)

Primary Examiner — Sang Kim
(74) *Attorney, Agent, or Firm* — Plumsea Law Group, LLC

(57) **ABSTRACT**

A tensioning system for articles of footwear and articles of apparel is disclosed. The tensioning system includes a tensioning member that is tightened or loosened using a motorized tensioning device for winding and unwinding the tensioning member on a spool. The tensioning system may be used with various sensors to determine how the motorized tensioning device should be controlled.

20 Claims, 43 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

3,187,342	A	6/1965	Aileo	
3,430,303	A	3/1969	Perrin et al.	
3,549,878	A	12/1970	Richard	
3,859,496	A	1/1975	Giese	
4,011,634	A	3/1977	Olivieri	
4,020,571	A	5/1977	Olivieri	
4,037,333	A	7/1977	Olivieri	
4,090,278	A	5/1978	Olivieri	
4,130,949	A	12/1978	Seidel	
4,253,217	A	3/1981	Marzocchi	
4,310,951	A	1/1982	Riedel	
4,326,320	A	4/1982	Riedel	
4,424,636	A	1/1984	Everest	
4,433,456	A	2/1984	Baggio	
4,453,290	A	6/1984	Riedel	
4,619,057	A	10/1986	Sartor et al.	
4,697,360	A	10/1987	Sartor	
4,724,626	A	2/1988	Baggio	
4,741,115	A	5/1988	Pozzobon	
4,780,968	A	11/1988	Bragagnolo	
4,787,124	A	11/1988	Pozzobon et al.	
4,800,659	A	1/1989	Marega	
4,802,290	A	2/1989	Marega	
4,841,649	A	6/1989	Baggio et al.	
4,942,678	A	7/1990	Gumbert	
5,105,566	A	4/1992	Legon	
5,129,130	A	7/1992	Lecouturier	
5,341,583	A	8/1994	Hallenbeck	
5,381,609	A	1/1995	Hieblinger	
5,425,185	A	6/1995	Gansler	
5,456,393	A	10/1995	Mathis et al.	
5,467,537	A	11/1995	Aveni et al.	
5,469,640	A	11/1995	Nichols	
5,495,682	A	3/1996	Chen	
5,555,650	A	9/1996	Longbottom et al.	
5,692,324	A	12/1997	Goldston et al.	
5,755,044	A	5/1998	Veylupek	
5,791,068	A	8/1998	Bernier et al.	
5,836,899	A	11/1998	Reilly	
5,839,210	A	11/1998	Bernier et al.	
5,934,599	A	8/1999	Hammerslag	
6,018,890	A	2/2000	Bowen	
6,032,387	A	3/2000	Johnson	
6,052,924	A	4/2000	Sabat	
6,148,489	A	11/2000	Dickie et al.	
6,202,953	B1	3/2001	Hammerslag	
6,289,558	B1	9/2001	Hammerslag	
6,289,609	B1	9/2001	Bowen	
6,427,361	B1	8/2002	Chou	
6,449,878	B1	9/2002	Lyden	
6,601,042	B1	7/2003	Lyden	
6,681,504	B2	1/2004	Kinan	
6,691,433	B2	2/2004	Liu	
6,751,490	B2	6/2004	Esenaliev et al.	
6,862,820	B2	3/2005	Farys et al.	
6,892,429	B2	5/2005	Sartor et al.	
6,922,917	B2	8/2005	Kerns et al.	
7,065,906	B2	6/2006	Jones et al.	
7,200,957	B2	4/2007	Hubbard et al.	
7,287,342	B2	10/2007	Keen	
7,310,895	B2 *	12/2007	Whittlesey et al.	36/137
7,367,522	B2	5/2008	Chen	
7,503,131	B2	3/2009	Nadel et al.	
7,584,528	B2	9/2009	Hu	
7,591,050	B2	9/2009	Hammerslag	
7,676,960	B2	3/2010	DiBenedetto et al.	
7,721,468	B1	5/2010	Johnson et al.	
7,752,774	B2	7/2010	Ussher	
7,950,112	B2	5/2011	Hammerslag et al.	
7,954,204	B2	6/2011	Hammerslag et al.	
7,980,009	B2	7/2011	Carnes et al.	
7,992,261	B2	8/2011	Hammerslag et al.	
8,020,320	B2	9/2011	Gillespie	
8,046,937	B2	11/2011	Beers et al.	
8,056,269	B2	11/2011	Beers et al.	
8,061,061	B1	11/2011	Rivas	
8,074,379	B2	12/2011	Robinson, Jr. et al.	
8,091,182	B2	1/2012	Hammerslag et al.	
8,141,277	B2	3/2012	Robinson et al.	
8,151,490	B2	4/2012	Sokolowski	
8,231,074	B2	7/2012	Hu et al.	
8,387,282	B2	3/2013	Baker et al.	
2002/0043007	A1	4/2002	Hannah	
2002/0095750	A1	7/2002	Hammerslag	
2004/0128863	A1	7/2004	Hong et al.	
2005/0098673	A1	5/2005	Huang	
2005/0102861	A1	5/2005	Martin	
2006/0000116	A1	1/2006	Brewer	
2006/0116483	A1	6/2006	Tonkel	
2006/0156517	A1	7/2006	Hammerslag et al.	
2006/0201031	A1	9/2006	Jones et al.	
2007/0000105	A1	1/2007	Grande et al.	
2007/0011914	A1	1/2007	Keen et al.	
2007/0043630	A1	2/2007	Lyden	
2007/0169378	A1	7/2007	Soderberg et al.	
2007/0278911	A1	12/2007	Vallance et al.	
2008/0060167	A1	3/2008	Hammerslag et al.	
2008/0066272	A1	3/2008	Hammerslag et al.	
2008/0222917	A1	9/2008	Dojan et al.	
2008/0235990	A1	10/2008	Wegener	
2008/0307673	A1	12/2008	Johnson	
2009/0055044	A1	2/2009	Dienst	
2009/0184189	A1	7/2009	Soderberg et al.	
2009/0205221	A1	8/2009	Mitchell	
2010/0139057	A1	6/2010	Soderberg et al.	
2010/0251524	A1	10/2010	Chen	
2010/0299959	A1	12/2010	Hammerslag et al.	
2011/0175744	A1	7/2011	Englert et al.	
2011/0225843	A1	9/2011	Kerns et al.	
2011/0258876	A1	10/2011	Baker et al.	
2011/0266384	A1	11/2011	Goodman et al.	
2012/0000091	A1	1/2012	Cotterman et al.	
2012/0004587	A1	1/2012	Nickel et al.	
2012/0005923	A1	1/2012	Beers et al.	
2012/0117821	A1	5/2012	Adams et al.	
2012/0192457	A1	8/2012	Youngs	
2013/0312293	A1	11/2013	Gerber	
2014/0068838	A1	3/2014	Beers et al.	
2014/0082963	A1	3/2014	Beers	
2014/0094728	A1	4/2014	Soderberg et al.	

FOREIGN PATENT DOCUMENTS

DE	101 09 673	A1	9/2002
DE	10 2005 036 013	A1	2/2007
EP	1064863	A1	1/2001
FR	2827486	A1	1/2003
GB	2 449 722	A	12/2008
JP	2005-036374	A	2/2005
WO	01/15559	A1	3/2001
WO	2009/071652	A1	6/2009
WO	2009/134858	A1	11/2009
WO	2014/036371	A1	3/2014
WO	2014/036374	A1	3/2014

OTHER PUBLICATIONS

International Search Report and Written Opinion mailed Dec. 22, 2014 in PCT/US2014/056207.

International Preliminary Report on Patentability (including Written Opinion of the ISA) mailed Mar. 12, 2015 in International Application No. PCT/US2013/057462.

International Preliminary Report on Patentability (including Written Opinion of the ISA) mailed Mar. 12, 2015 in International Application No. PCT/US2013/057467.

International Search Report and Written Opinion dated Jan. 3, 2014 cited in PCT/US2013/057462.

International Search Report and Written Opinion dated Jan. 3, 2014 cited in PCT/US2013/057467.

* cited by examiner

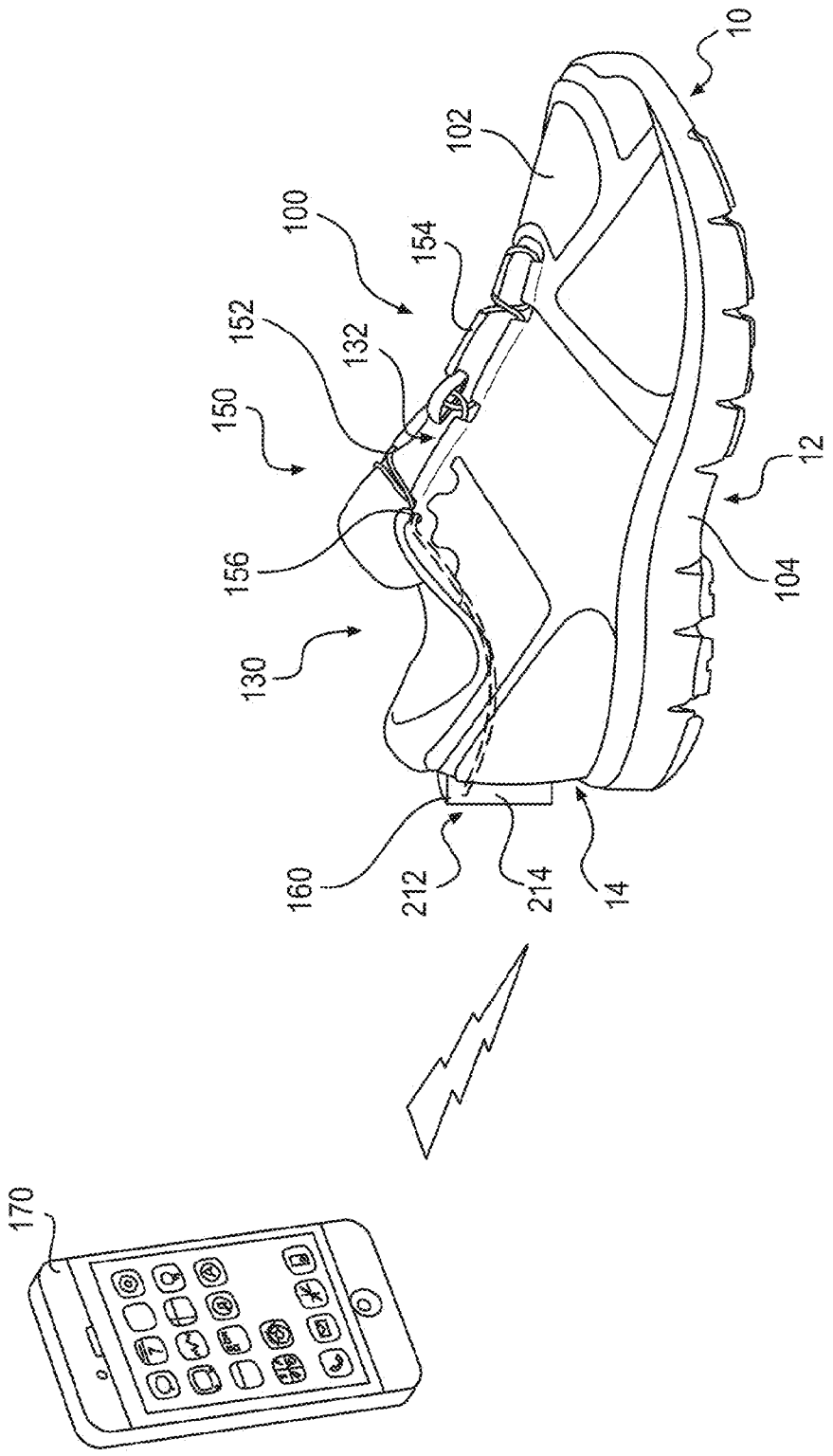


FIG. 1

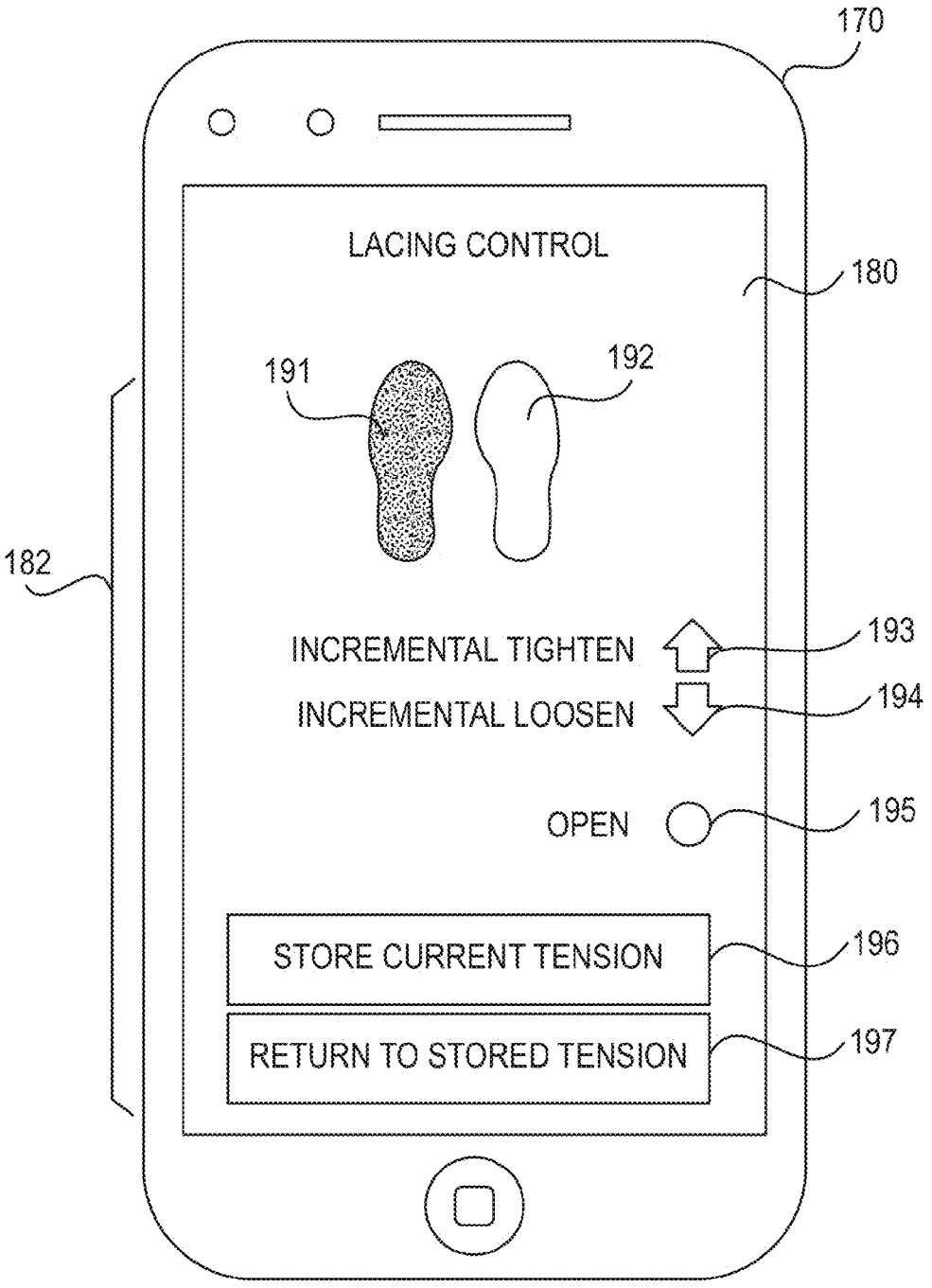

170
LACING CONTROL
180
191
192
182
INCREMENTAL TIGHTEN
193
INCREMENTAL LOOSEN
194
OPEN
195
STORE CURRENT TENSION
196
RETURN TO STORED TENSION
197

FIG. 2

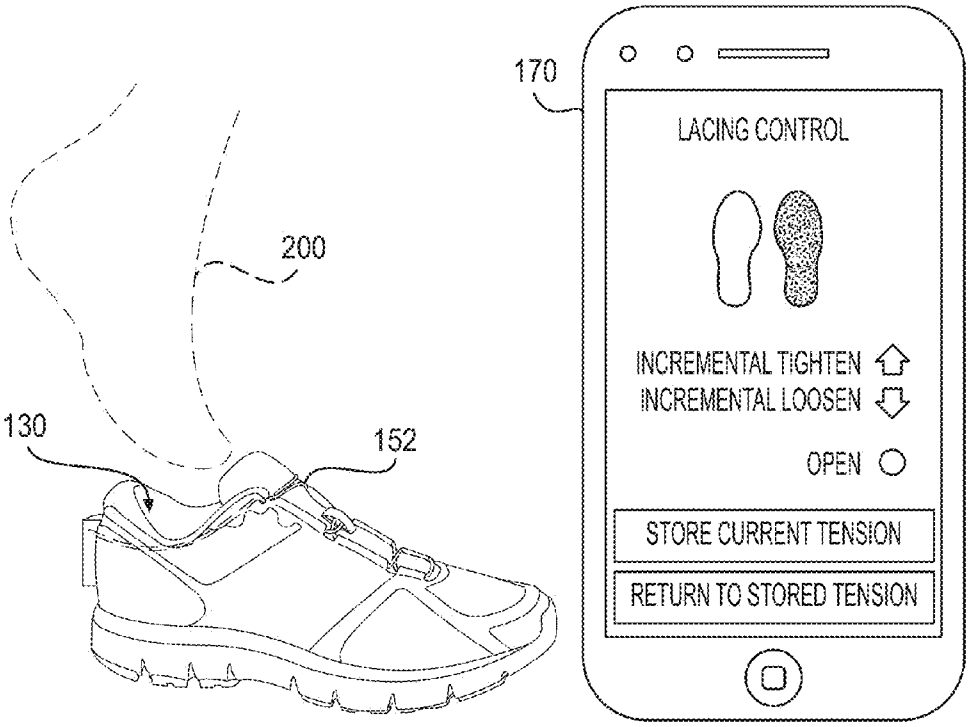

170
LACING CONTROL
INCREMENTAL TIGHTEN
INCREMENTAL LOOSEN
OPEN
STORE CURRENT TENSION
RETURN TO STORED TENSION
200
130
152

FIG. 3

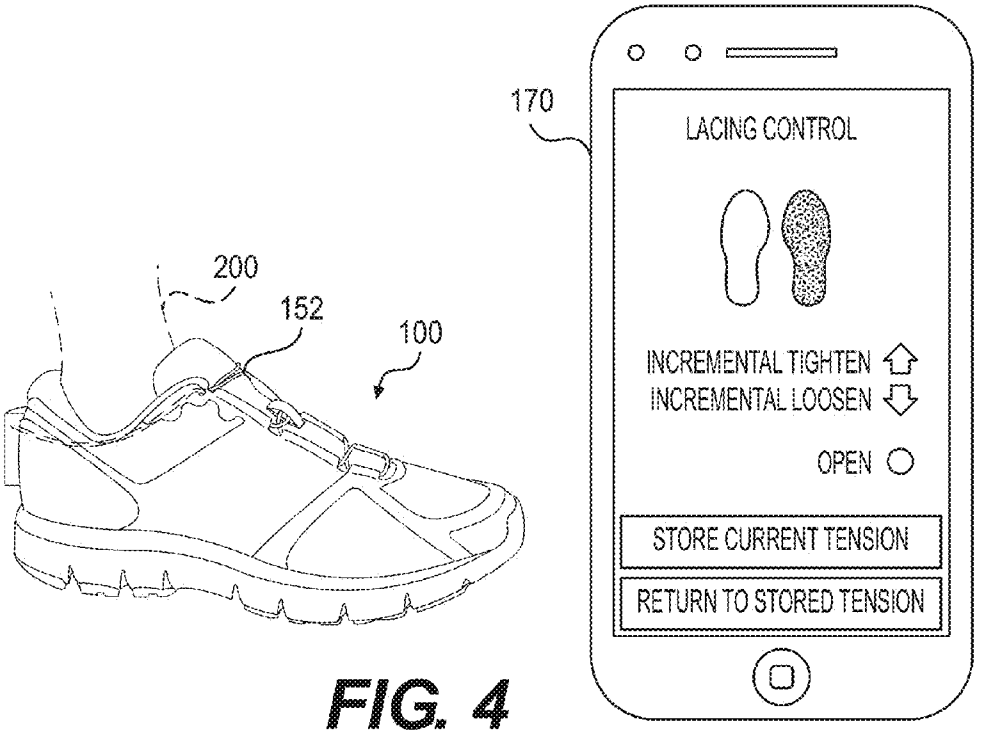

170
LACING CONTROL
INCREMENTAL TIGHTEN
INCREMENTAL LOOSEN
OPEN
STORE CURRENT TENSION
RETURN TO STORED TENSION
200
152
100

FIG. 4

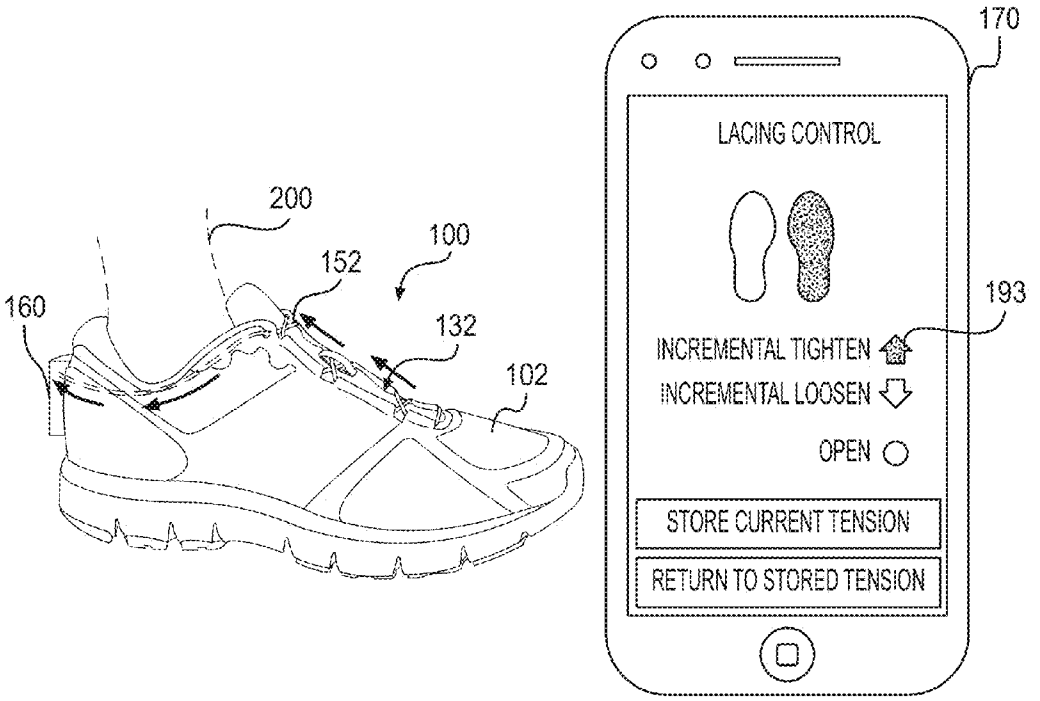

200
100
152
160
132
102
170
LACING CONTROL
193
INCREMENTAL TIGHTEN
INCREMENTAL LOOSEN
OPEN
STORE CURRENT TENSION
RETURN TO STORED TENSION

FIG. 5

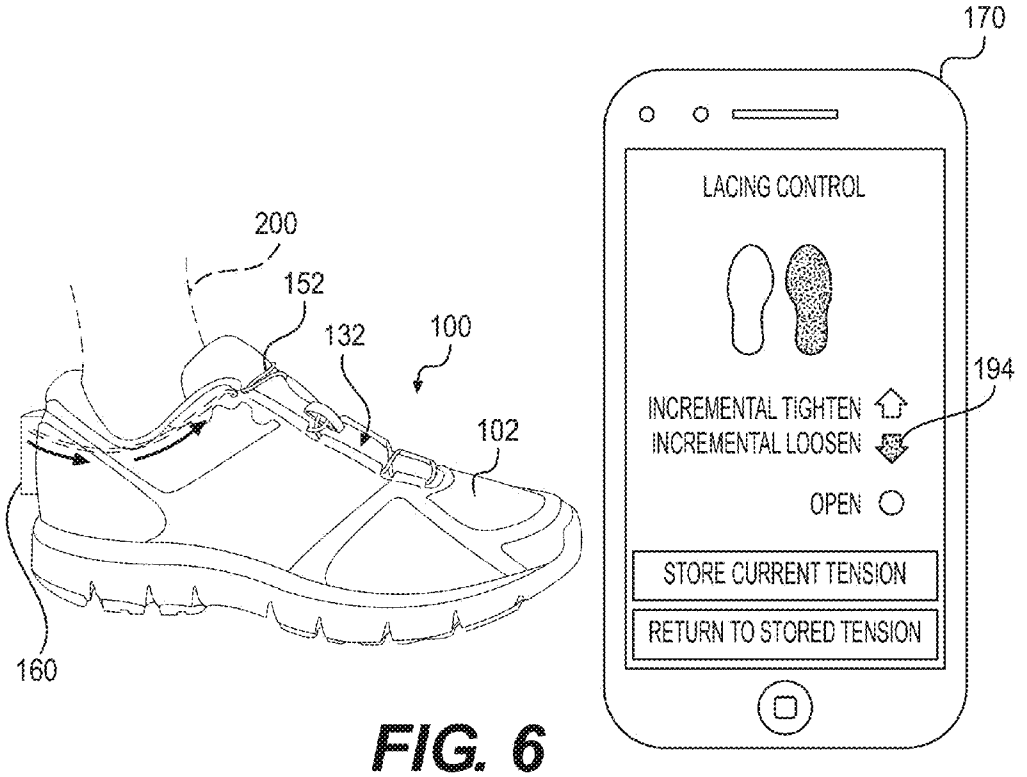

200
152
132
100
102
160
170
LACING CONTROL
194
INCREMENTAL TIGHTEN
INCREMENTAL LOOSEN
OPEN
STORE CURRENT TENSION
RETURN TO STORED TENSION

FIG. 6

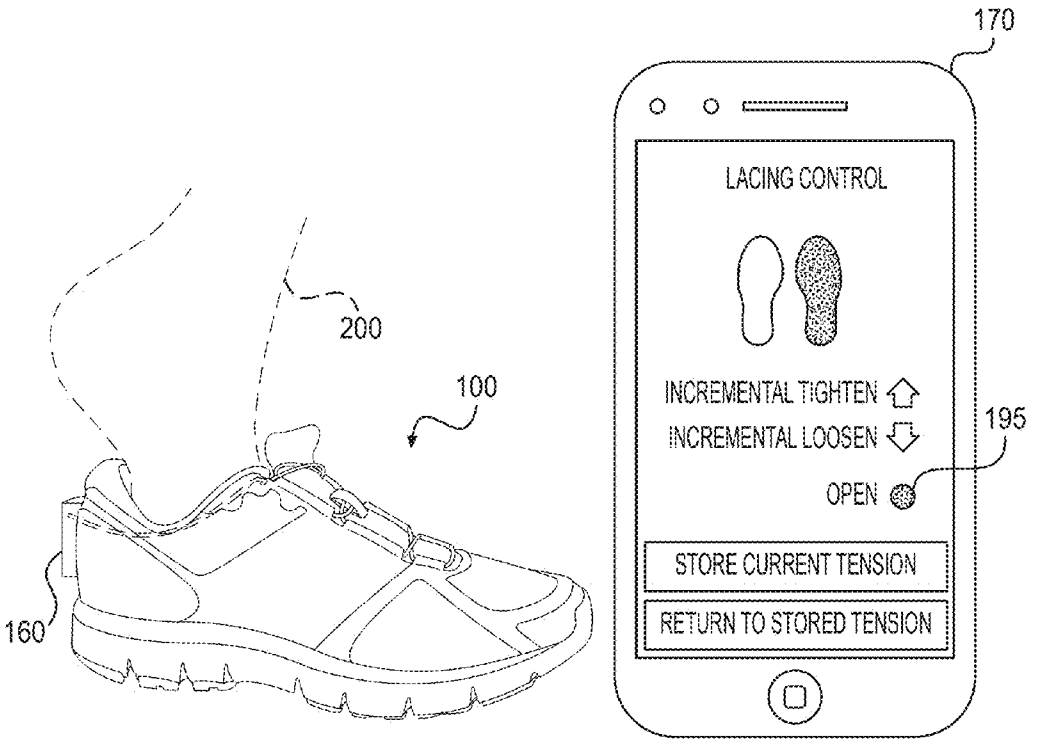

170
LACING CONTROL
INCREMENTAL TIGHTEN
INCREMENTAL LOOSEN
OPEN
195
STORE CURRENT TENSION
RETURN TO STORED TENSION
200
100
160

FIG. 7

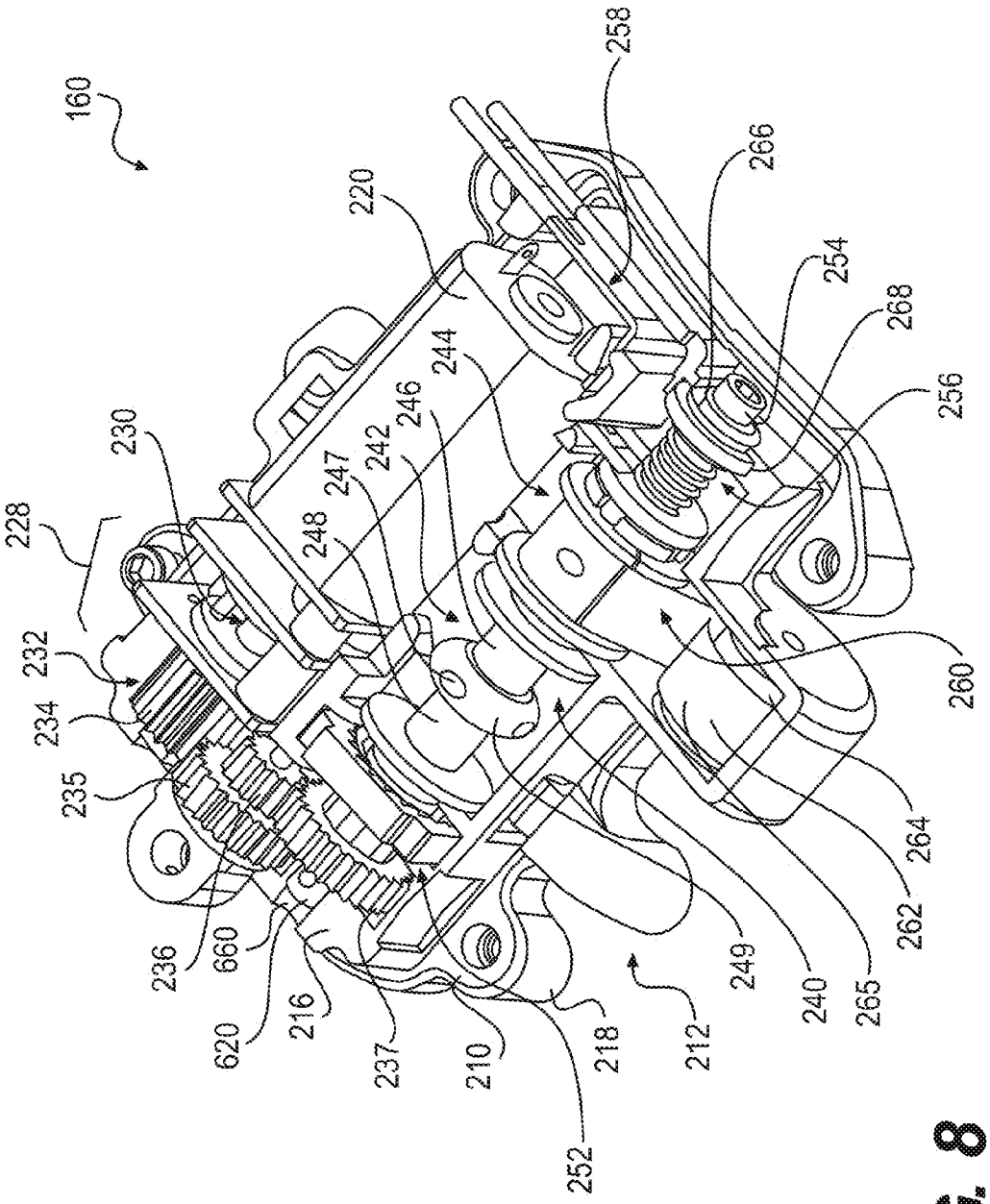

160
258
266
220
254
268
244
246
242
247
230
256
228
248
232
260
234
235
264
262
236
660
249
240
265
620
216
237
210
218
212
252

FIG. 8

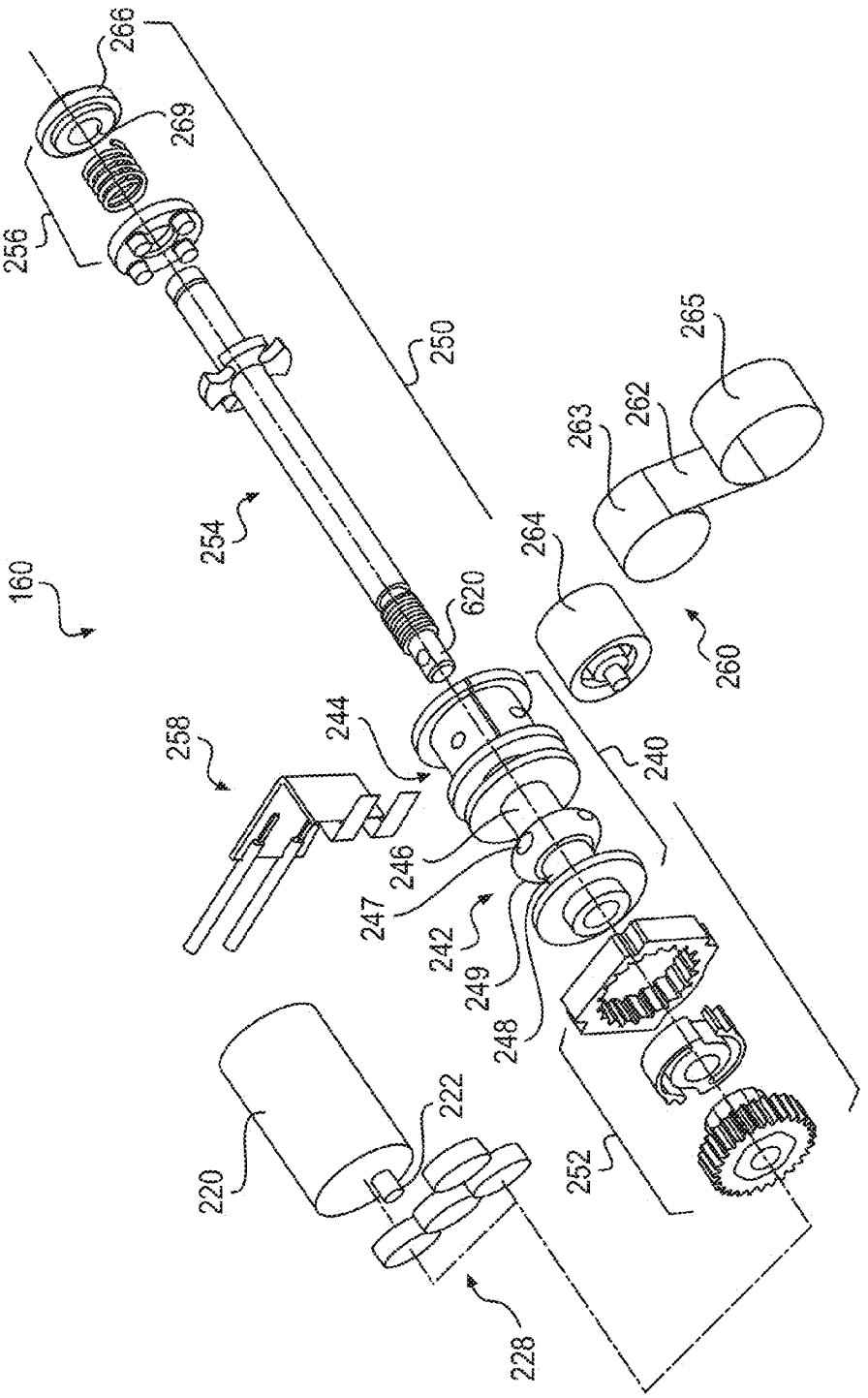

266
269
256
250
265
263
262
254
264
160
620
260
258
244
240
246
247
242
249
248
222
220
252
228

FIG. 9

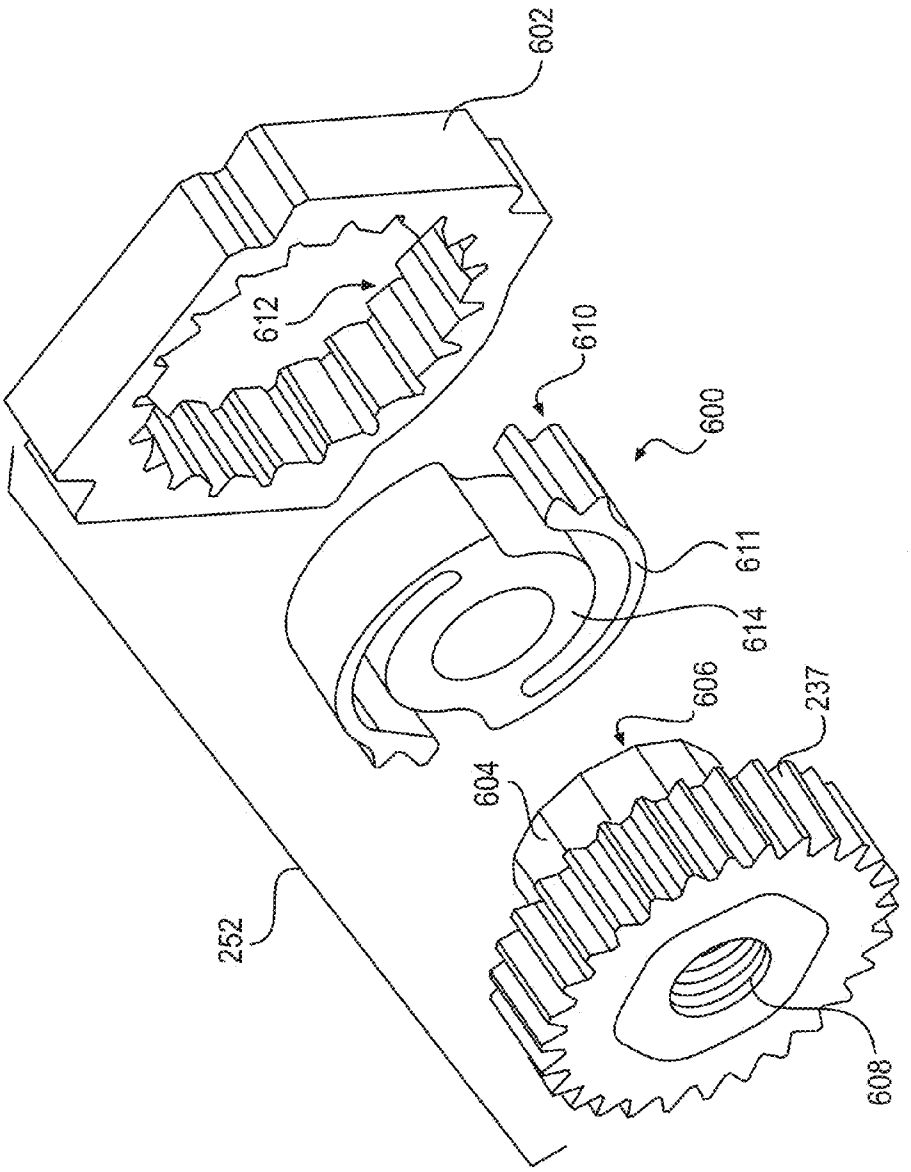


FIG. 10

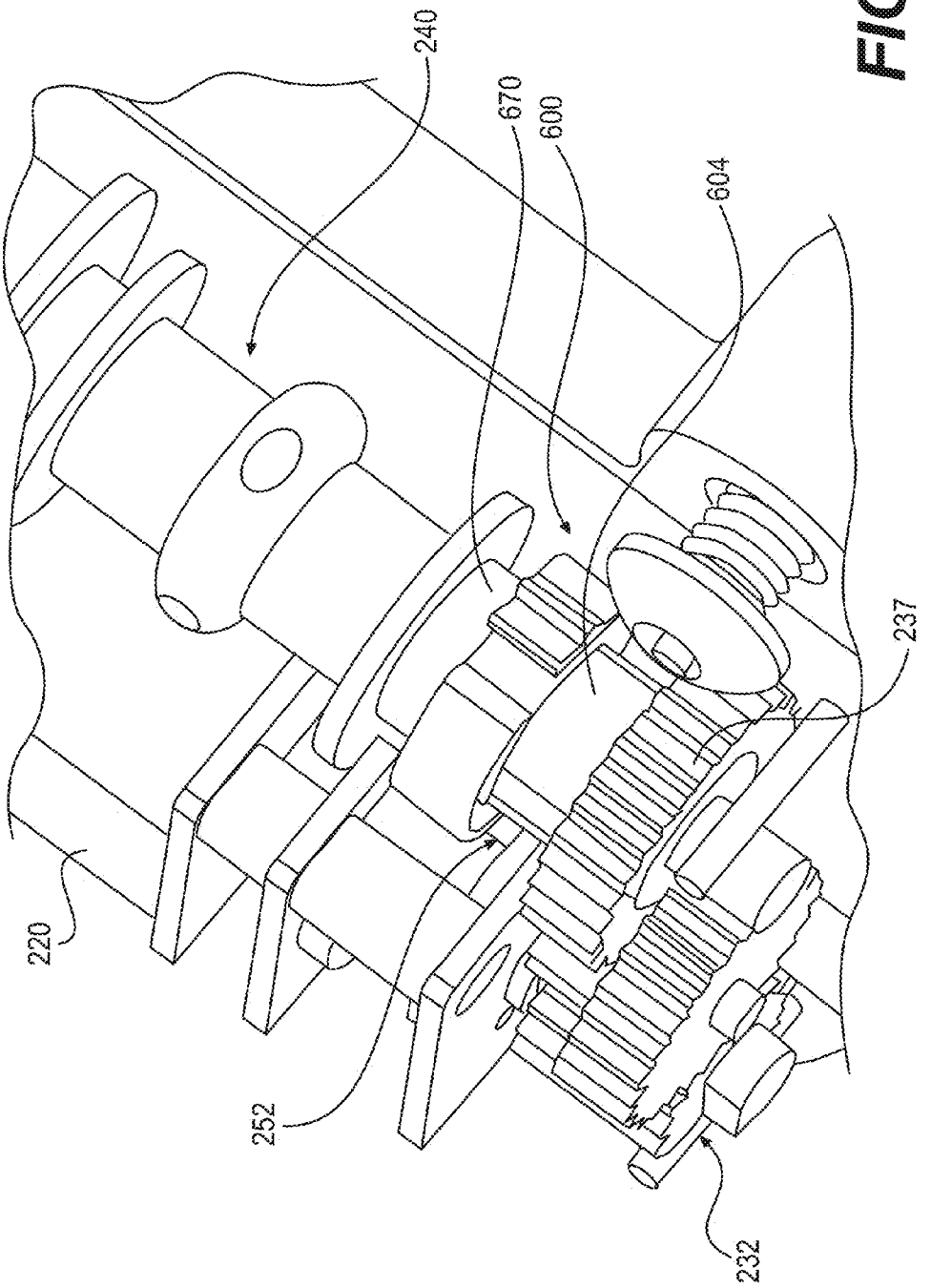


FIG. 11

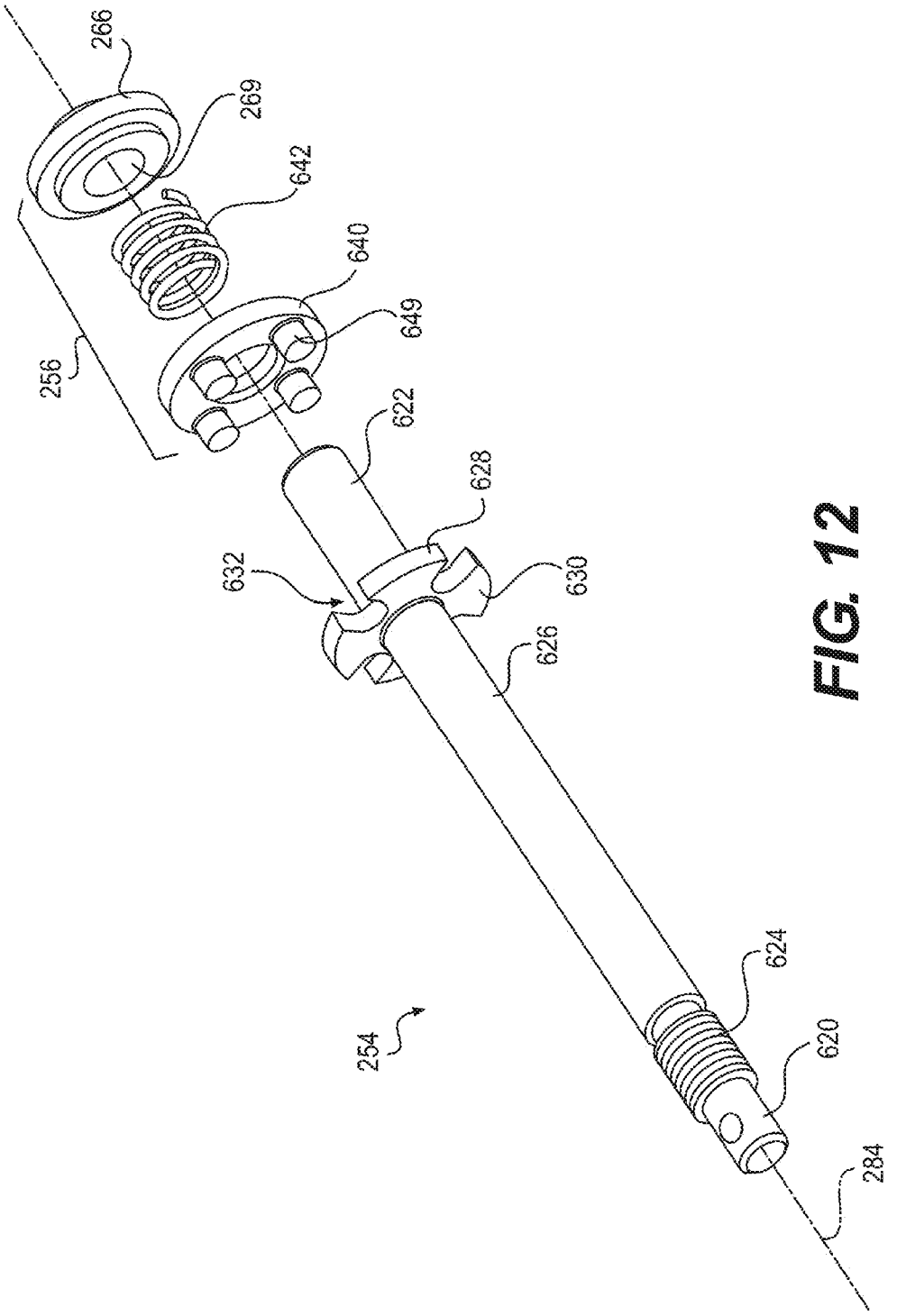


FIG. 12

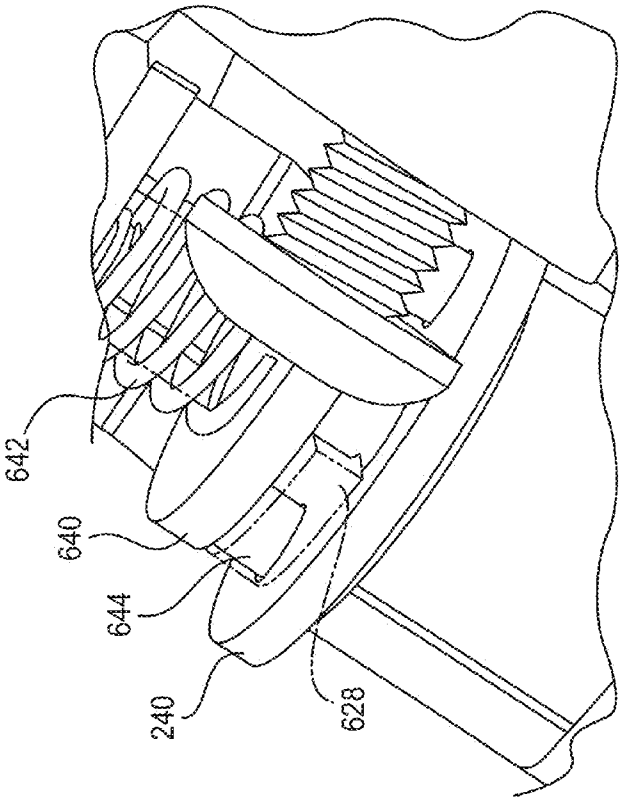


FIG. 14

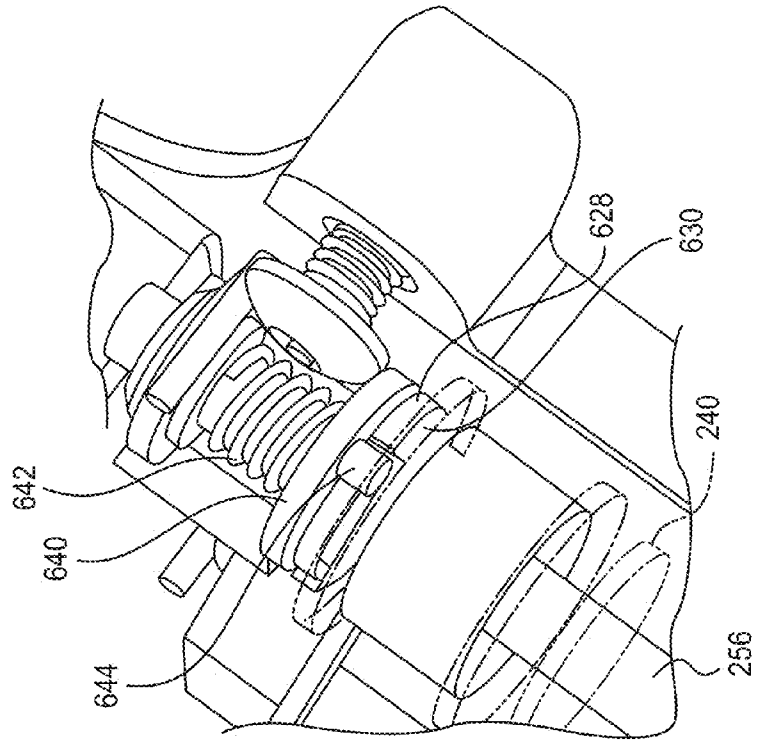


FIG. 13

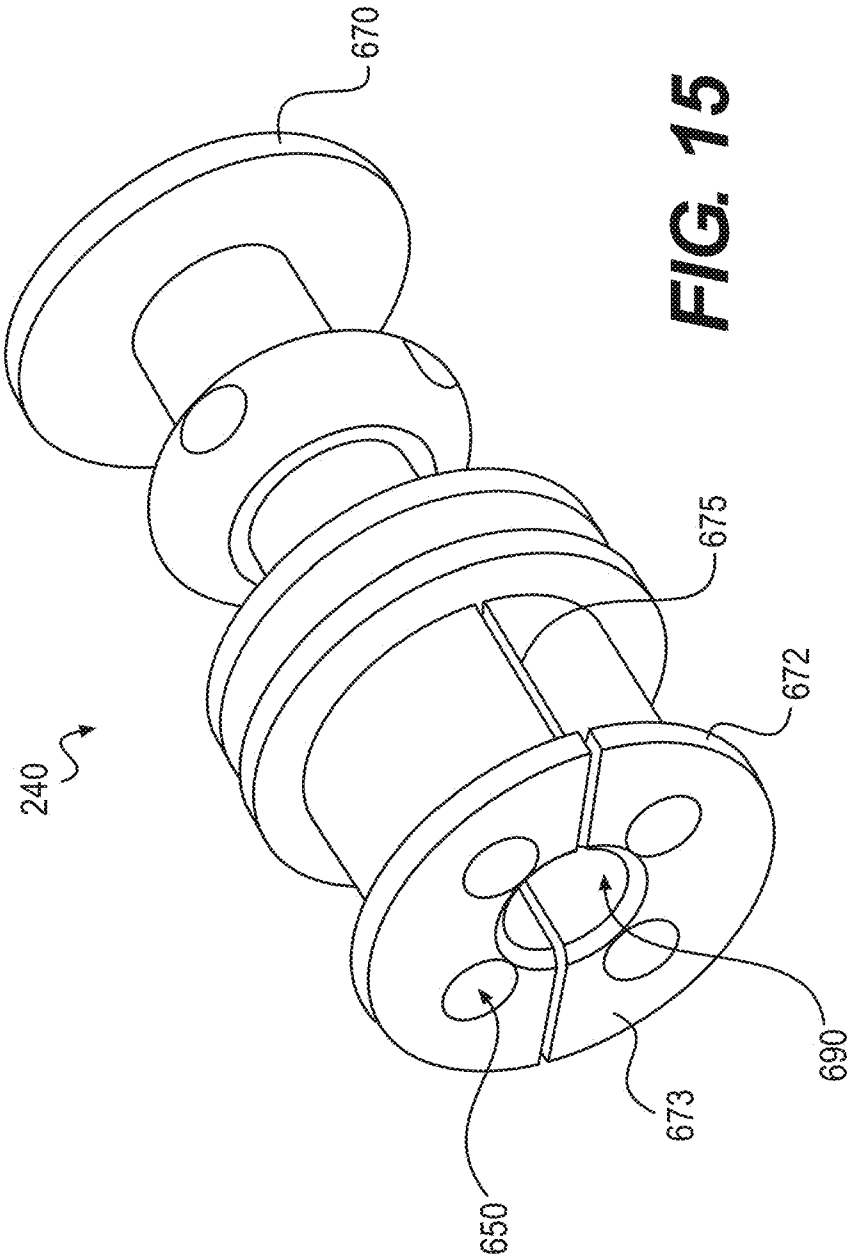


FIG. 15

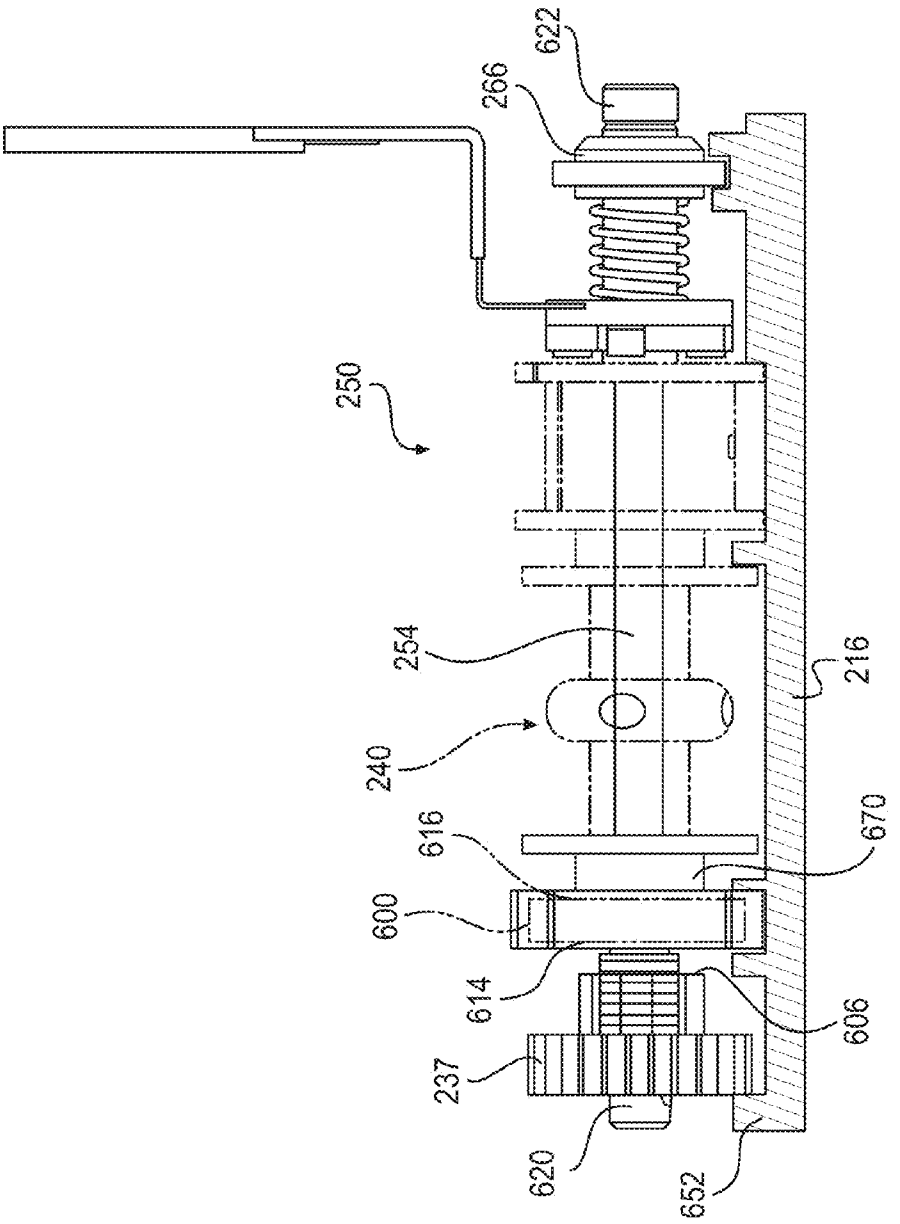


FIG. 16

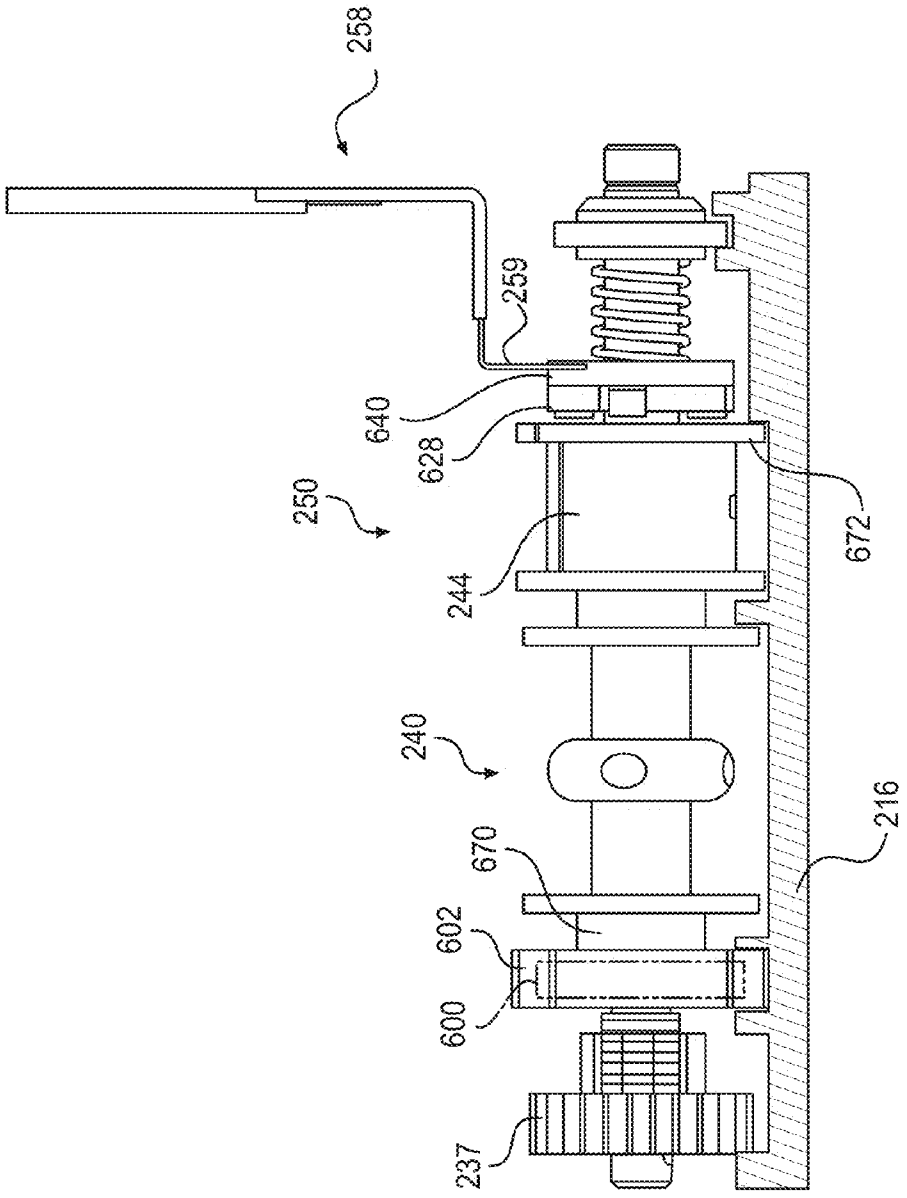


FIG. 17

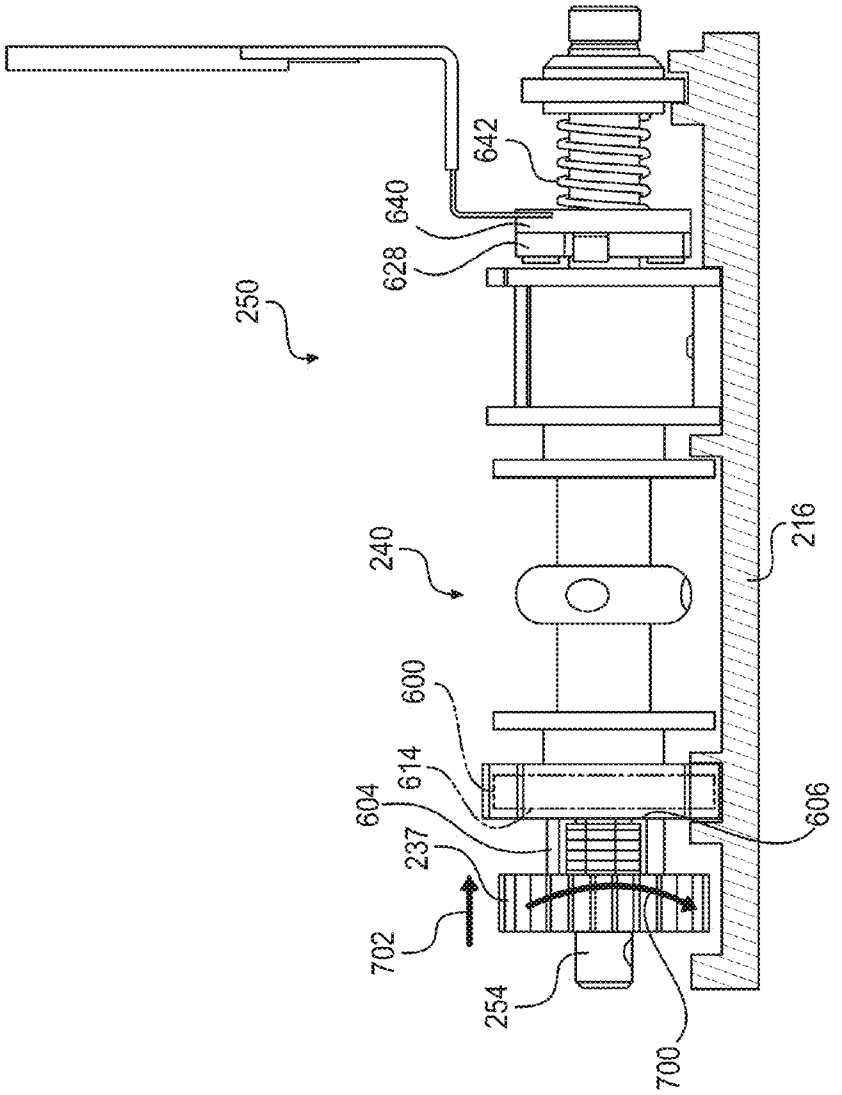


FIG. 18

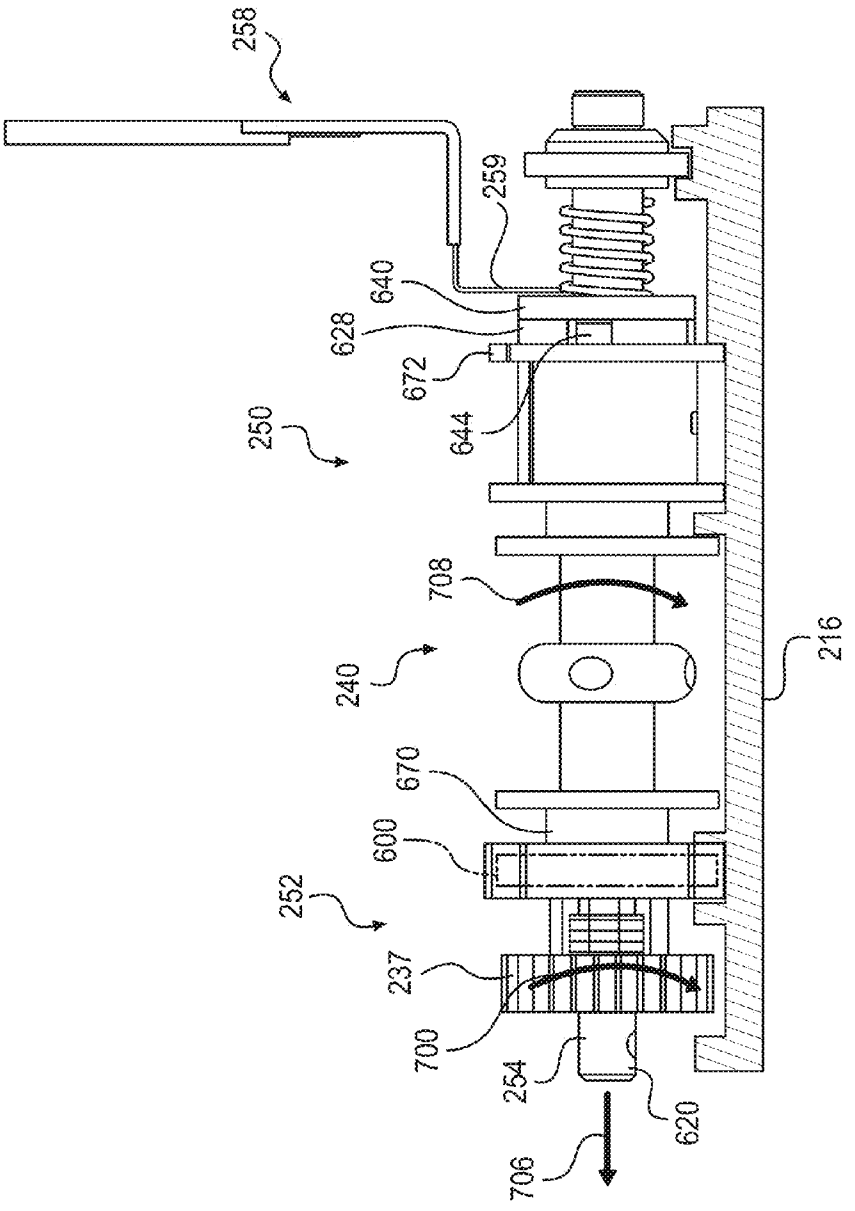

258
259
640
628
672
644
250
708
240
216
670
600
252
237
700
254
620
706

FIG. 19

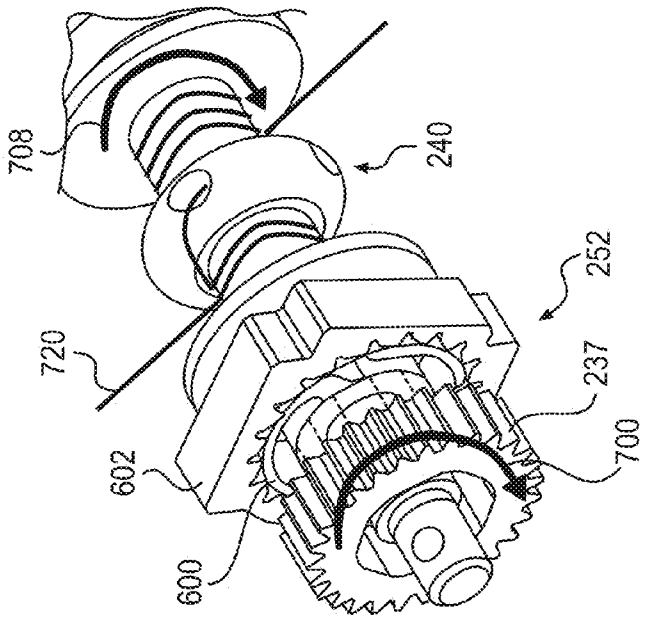


FIG. 21

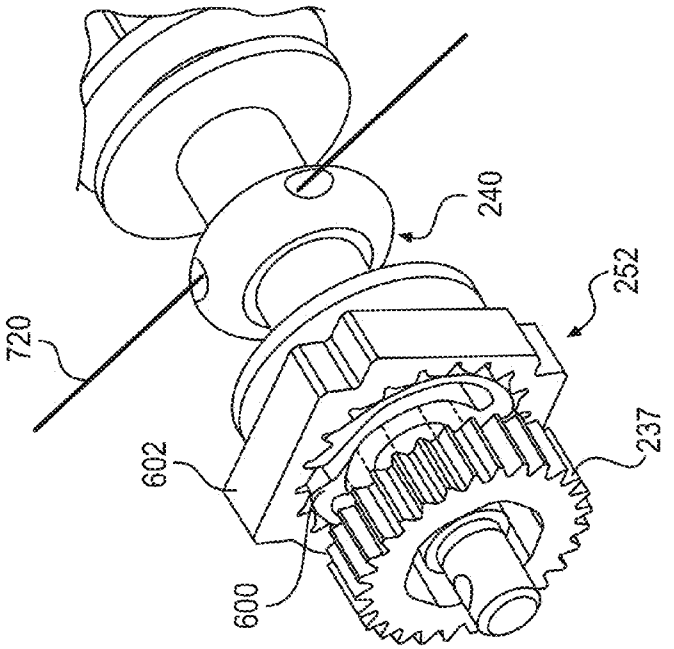


FIG. 20

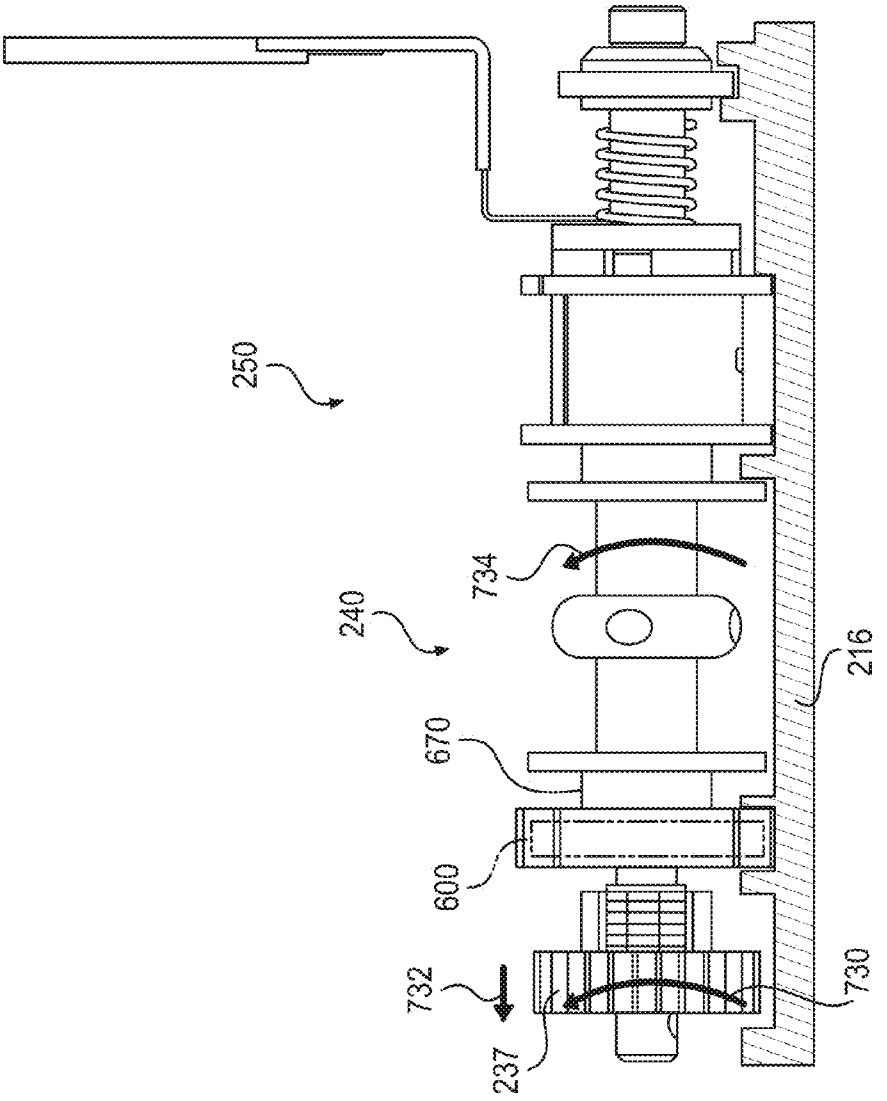


FIG. 22

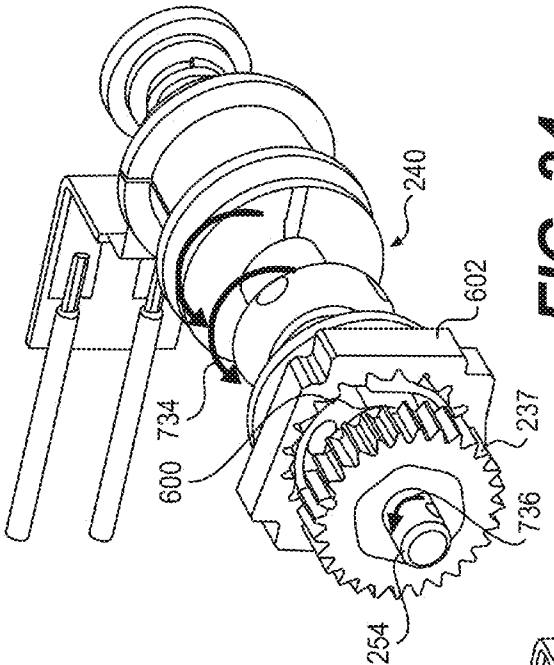


FIG. 24

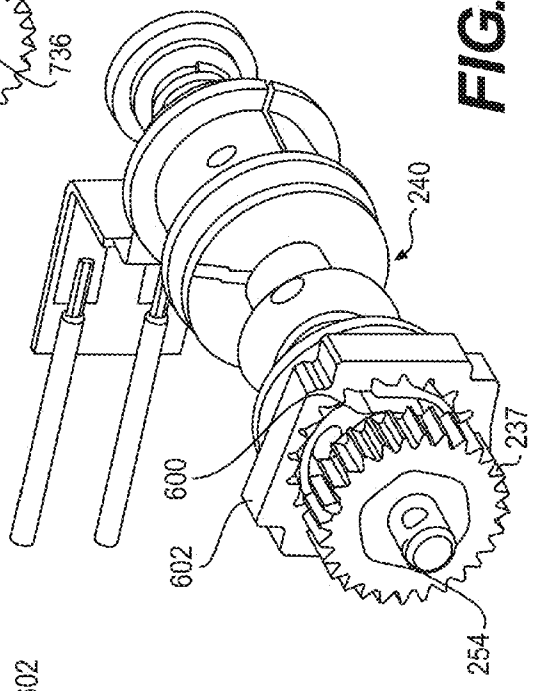


FIG. 25

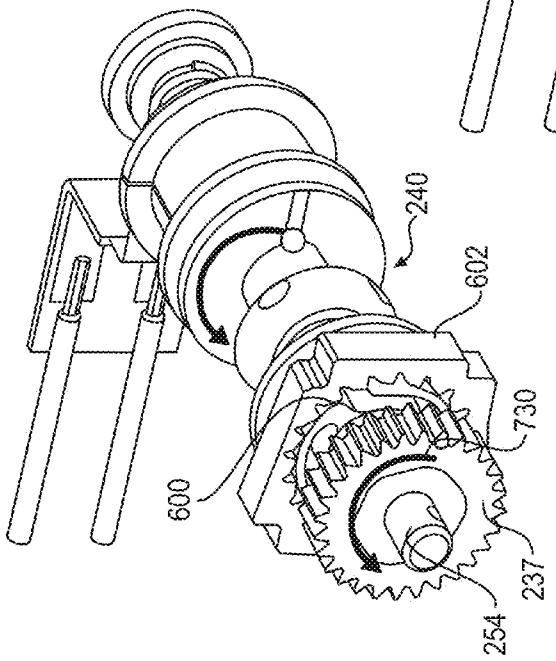


FIG. 23

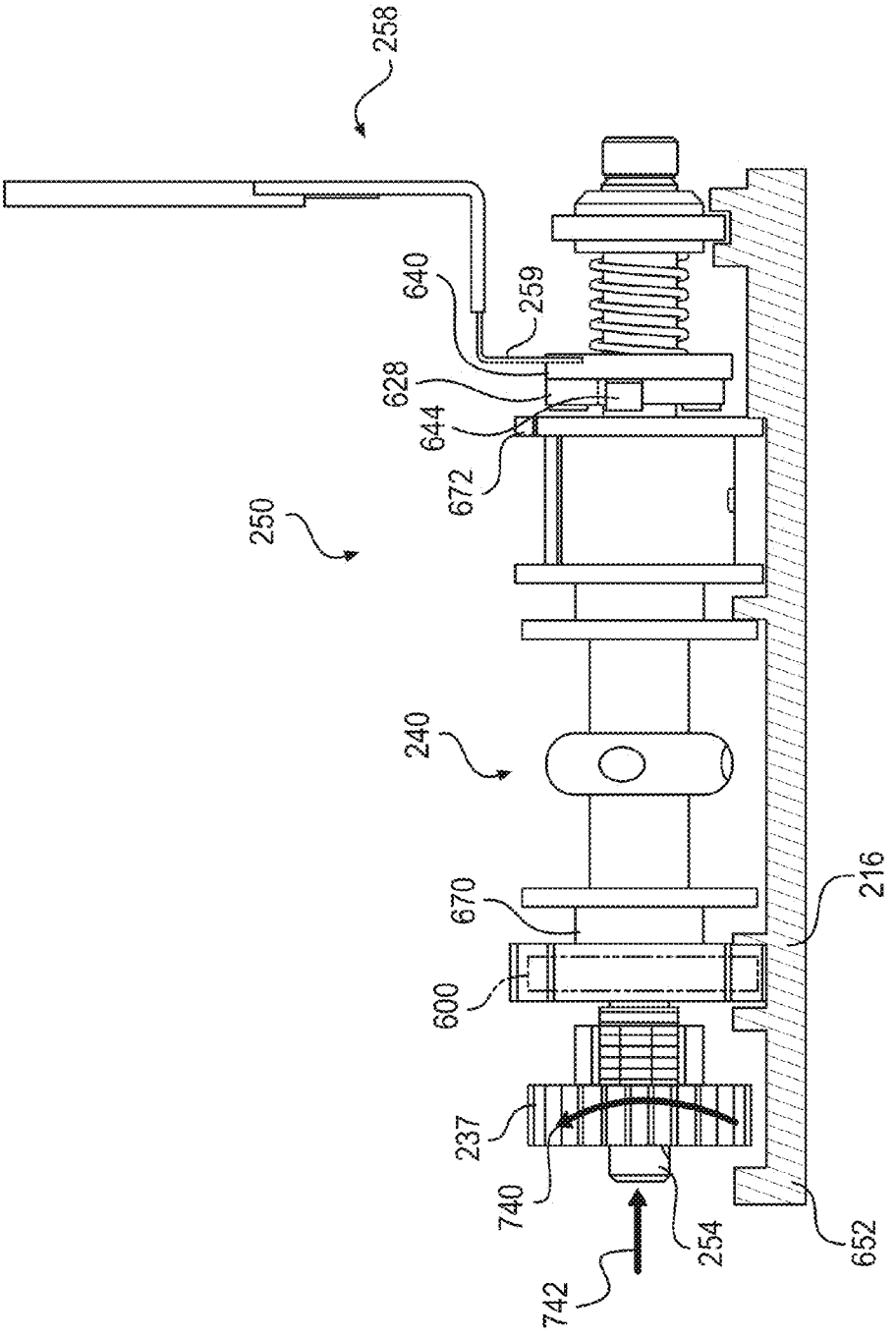


FIG. 26

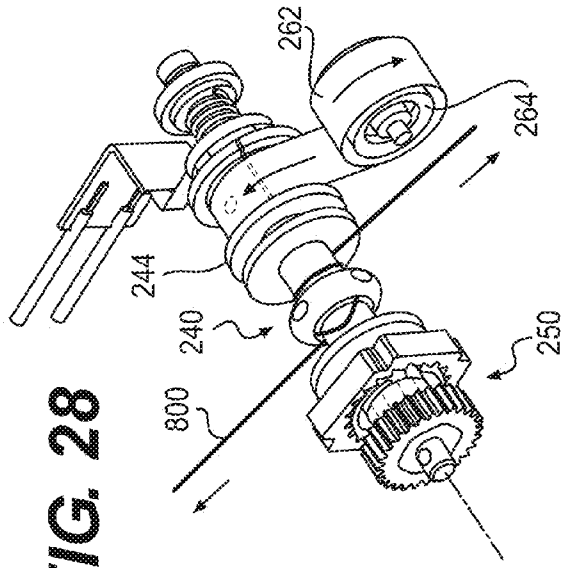


FIG. 28

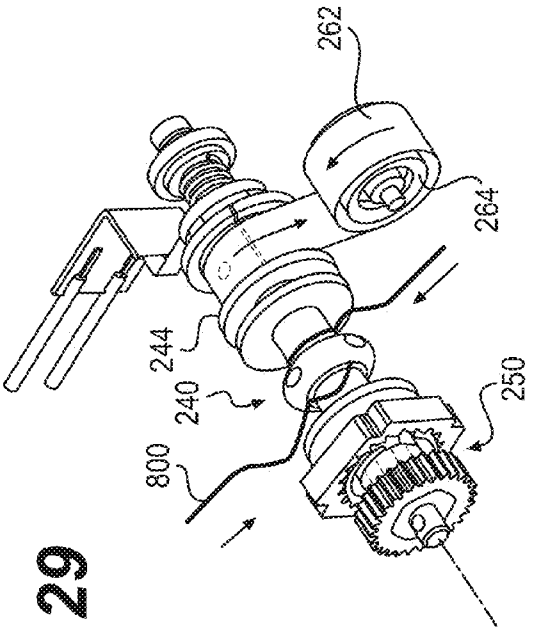


FIG. 29

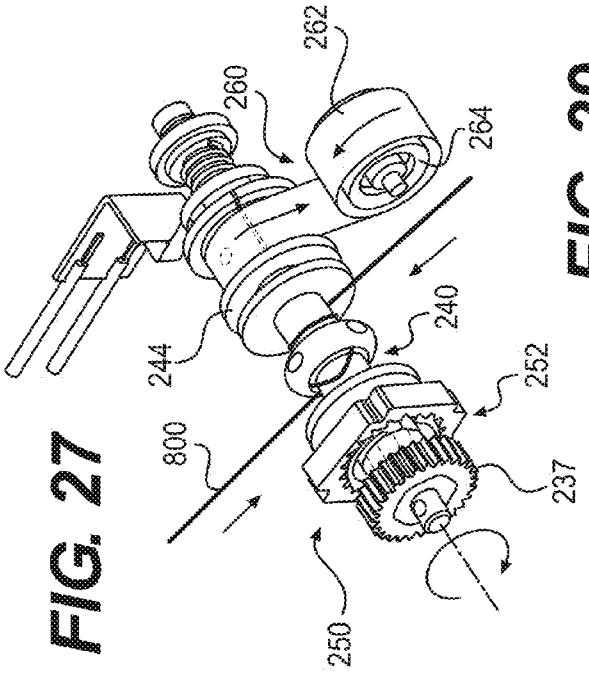


FIG. 27

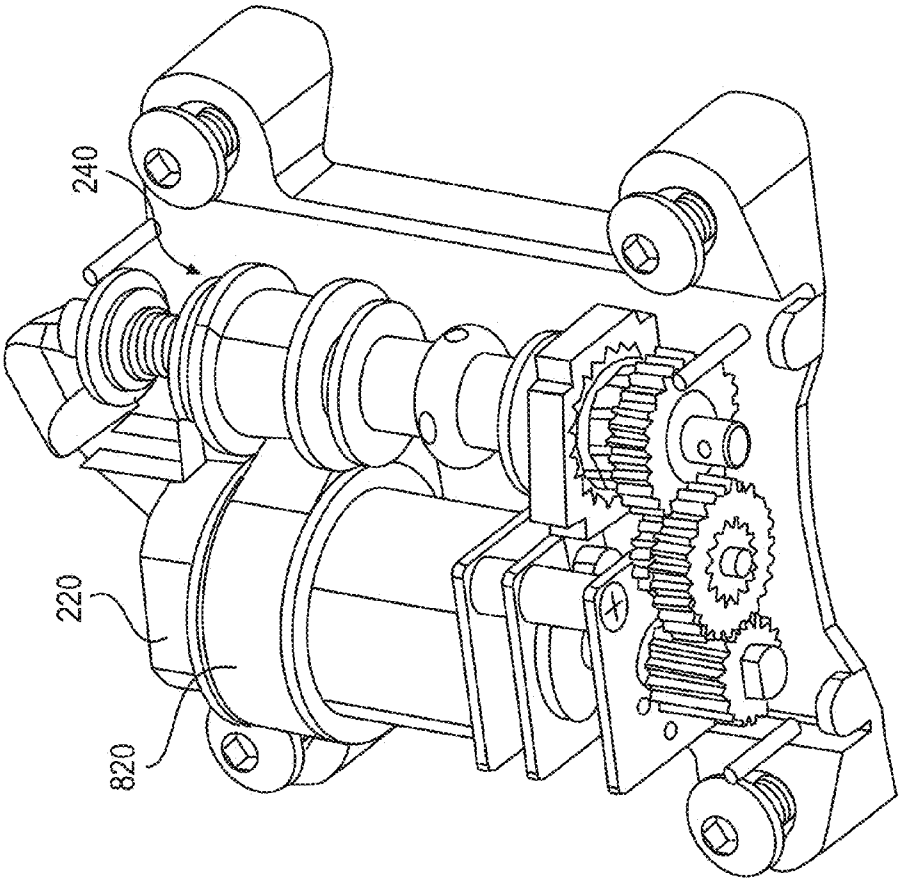


FIG. 30

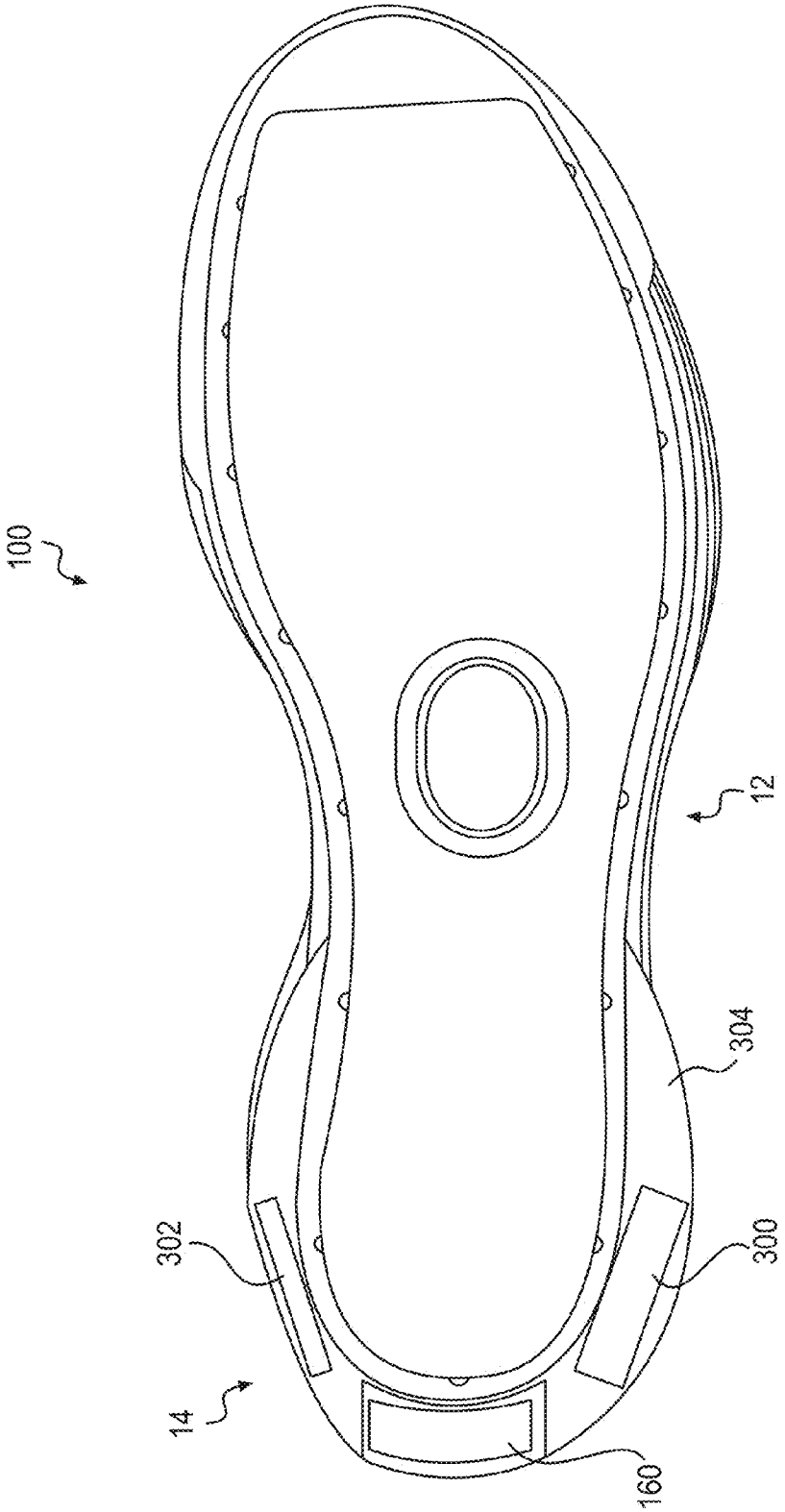


FIG. 31

FIG. 32

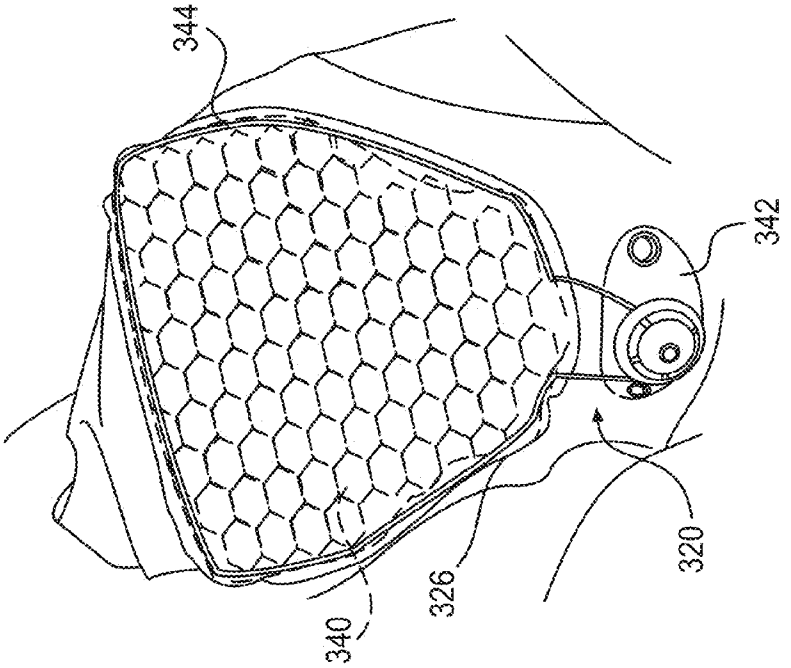


FIG. 34

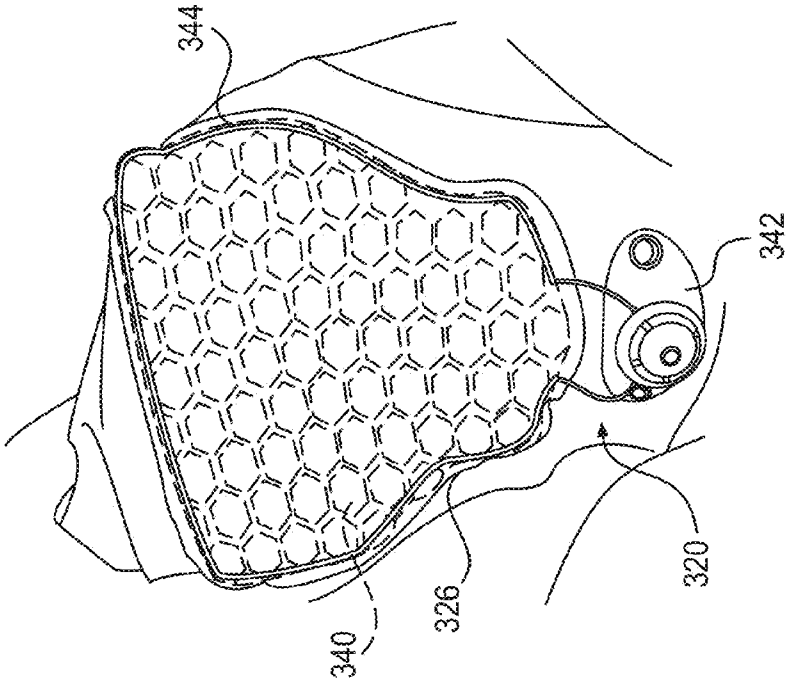


FIG. 33

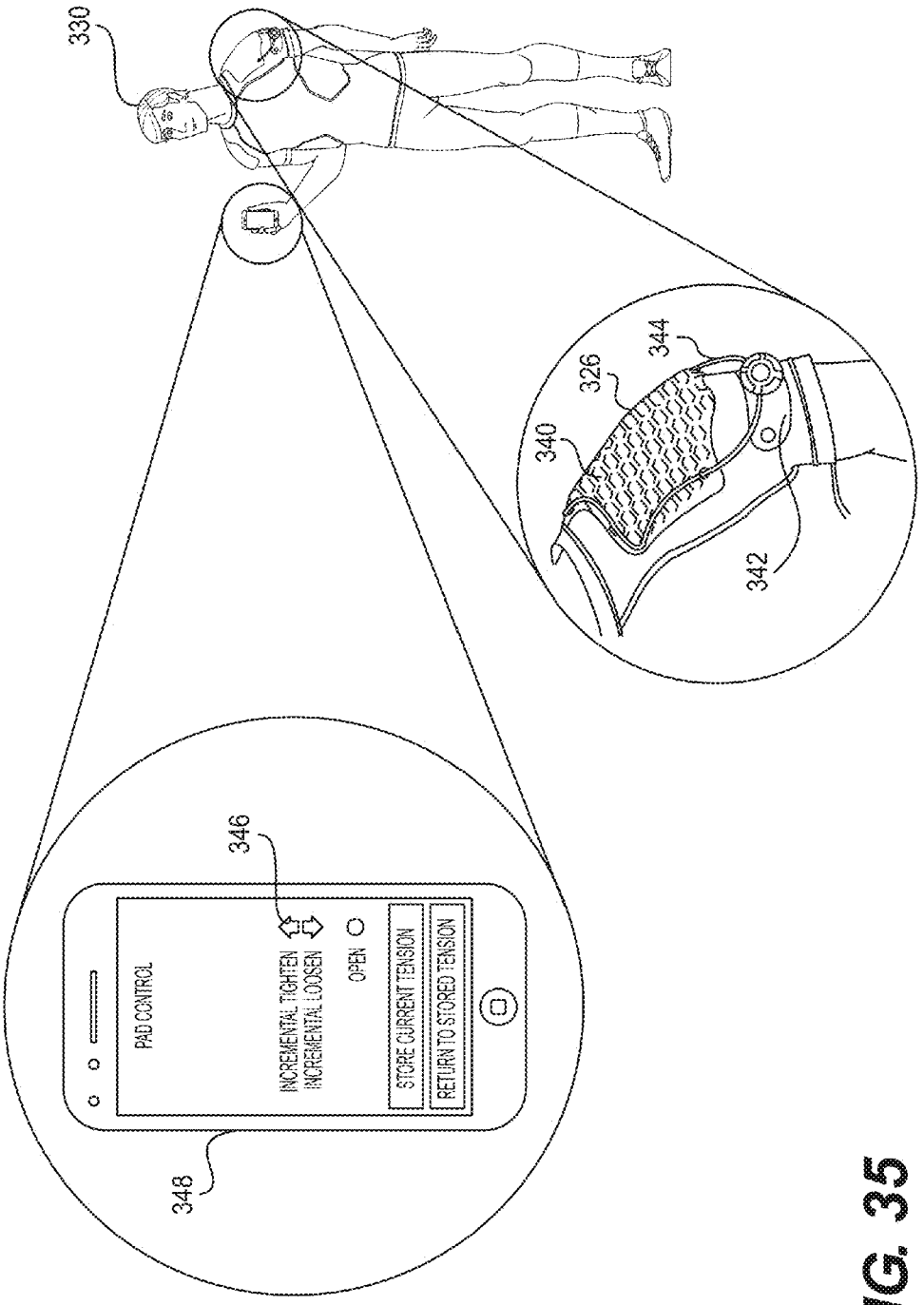

330
344
326
340
342
346
348
PAD CONTROL
INCREMENTAL TIGHTEN
INCREMENTAL LOOSEN
OPEN
STORE CURRENT TENSION
RETURN TO STORED TENSION

FIG. 35

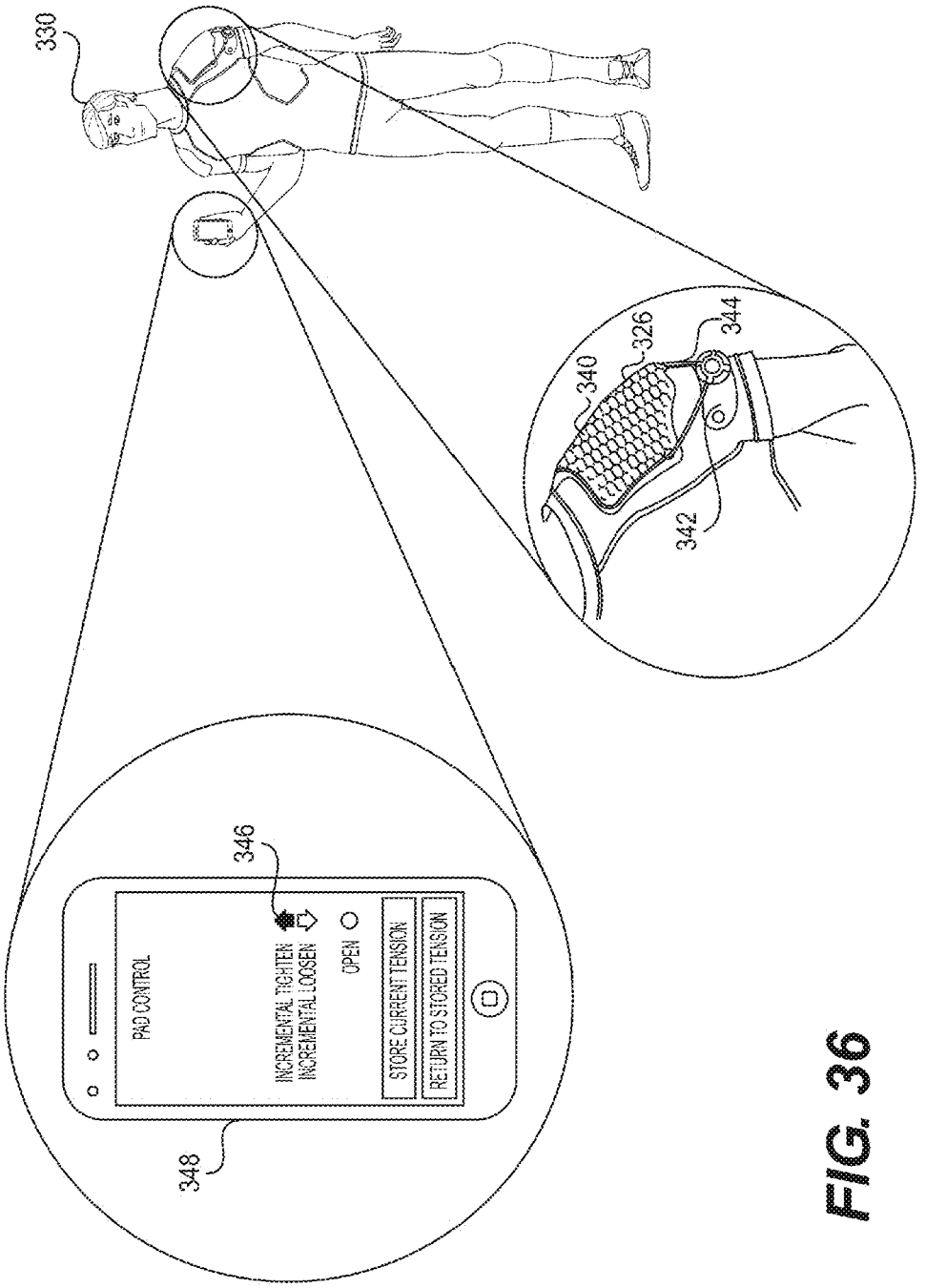

330
340
326
344
342
346
348
PAD CONTROL
INCREMENTAL TIGHTEN
INCREMENTAL LOOSEN
OPEN
STORE CURRENT TENSION
RETURN TO STORED TENSION

FIG. 36

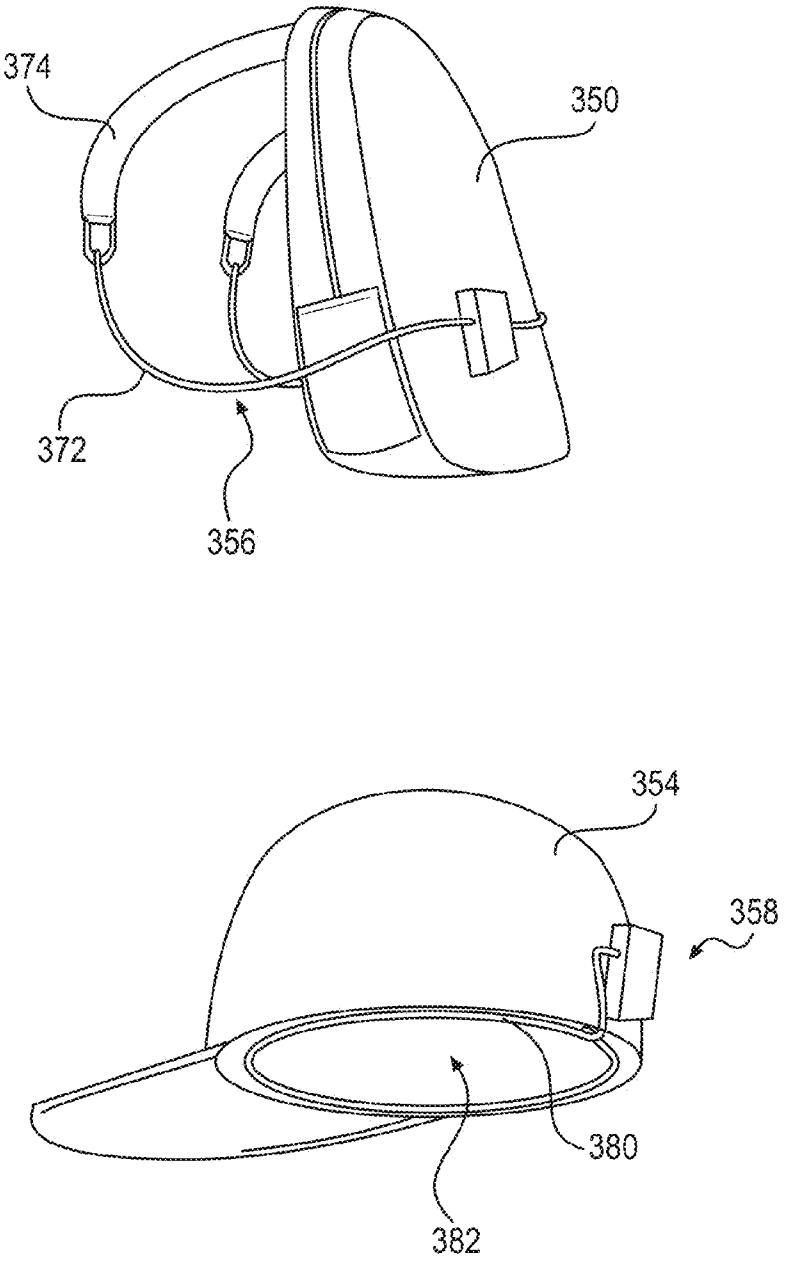


FIG. 37

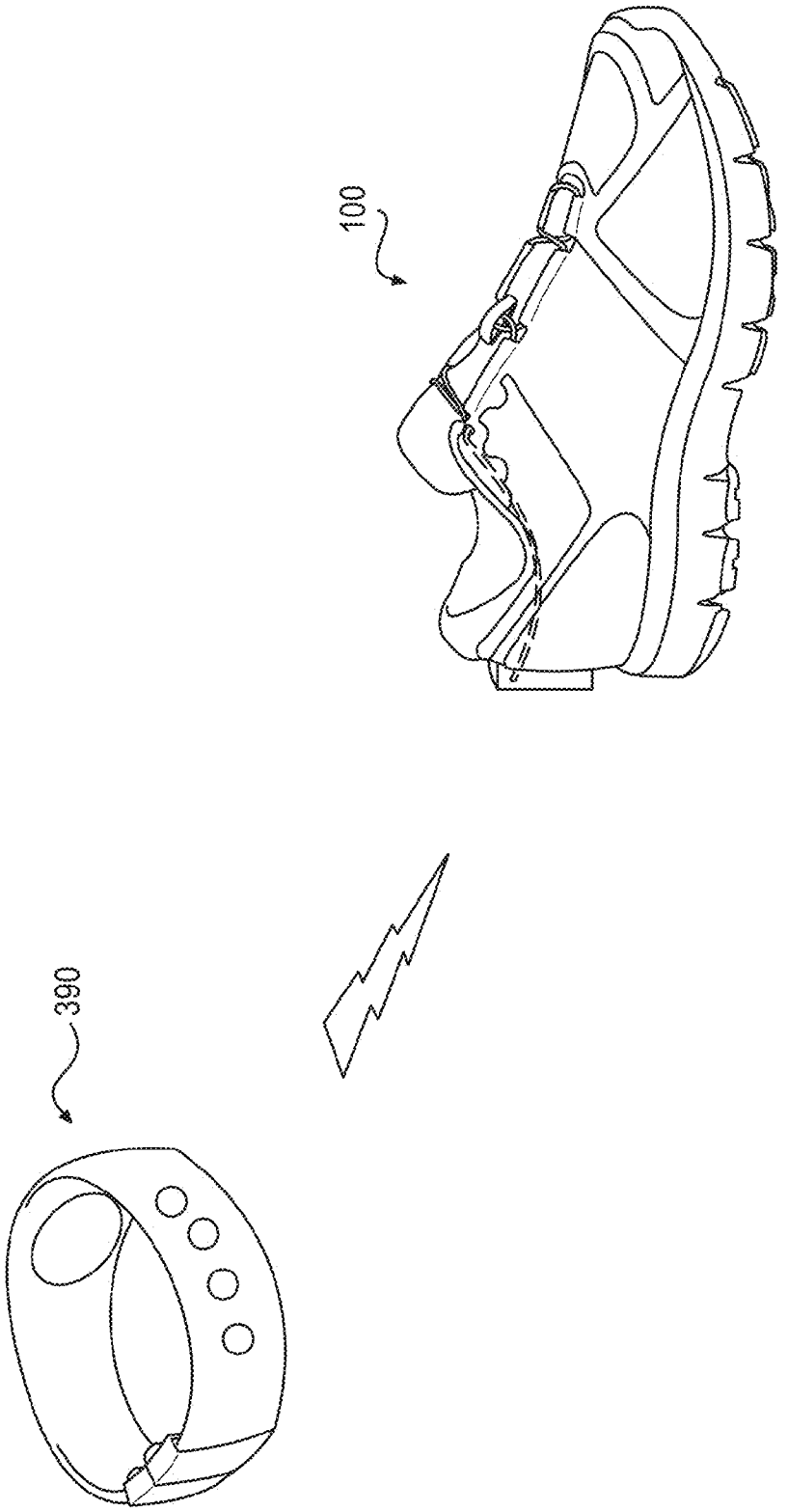


FIG. 38

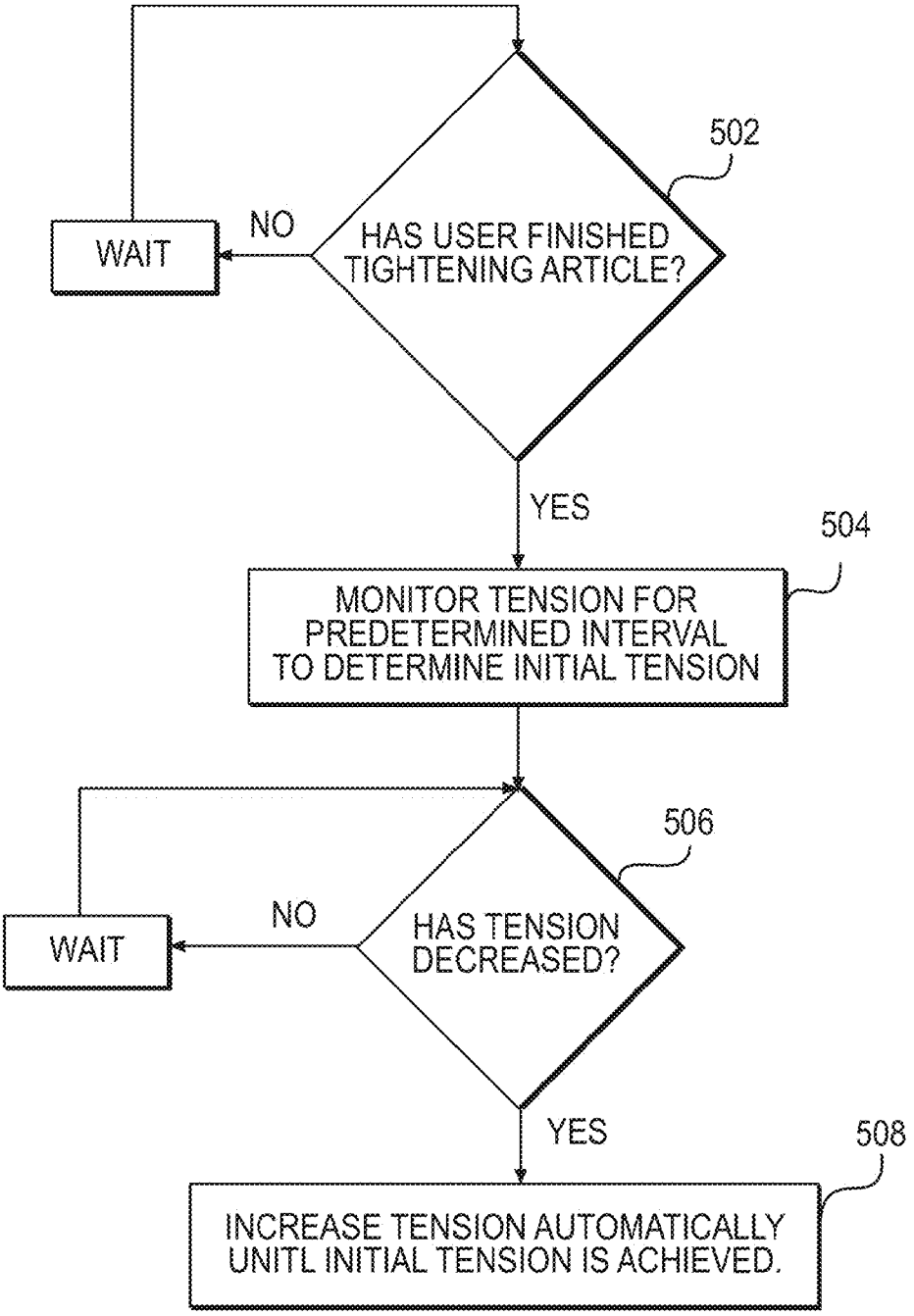

502
HAS USER FINISHED TIGHTENING ARTICLE?
NO
WAIT
YES
504
MONITOR TENSION FOR PREDETERMINED INTERVAL TO DETERMINE INITIAL TENSION
506
HAS TENSION DECREASED?
NO
WAIT
YES
508
INCREASE TENSION AUTOMATICALLY UNITL INITIAL TENSION IS ACHIEVED.

FIG. 39

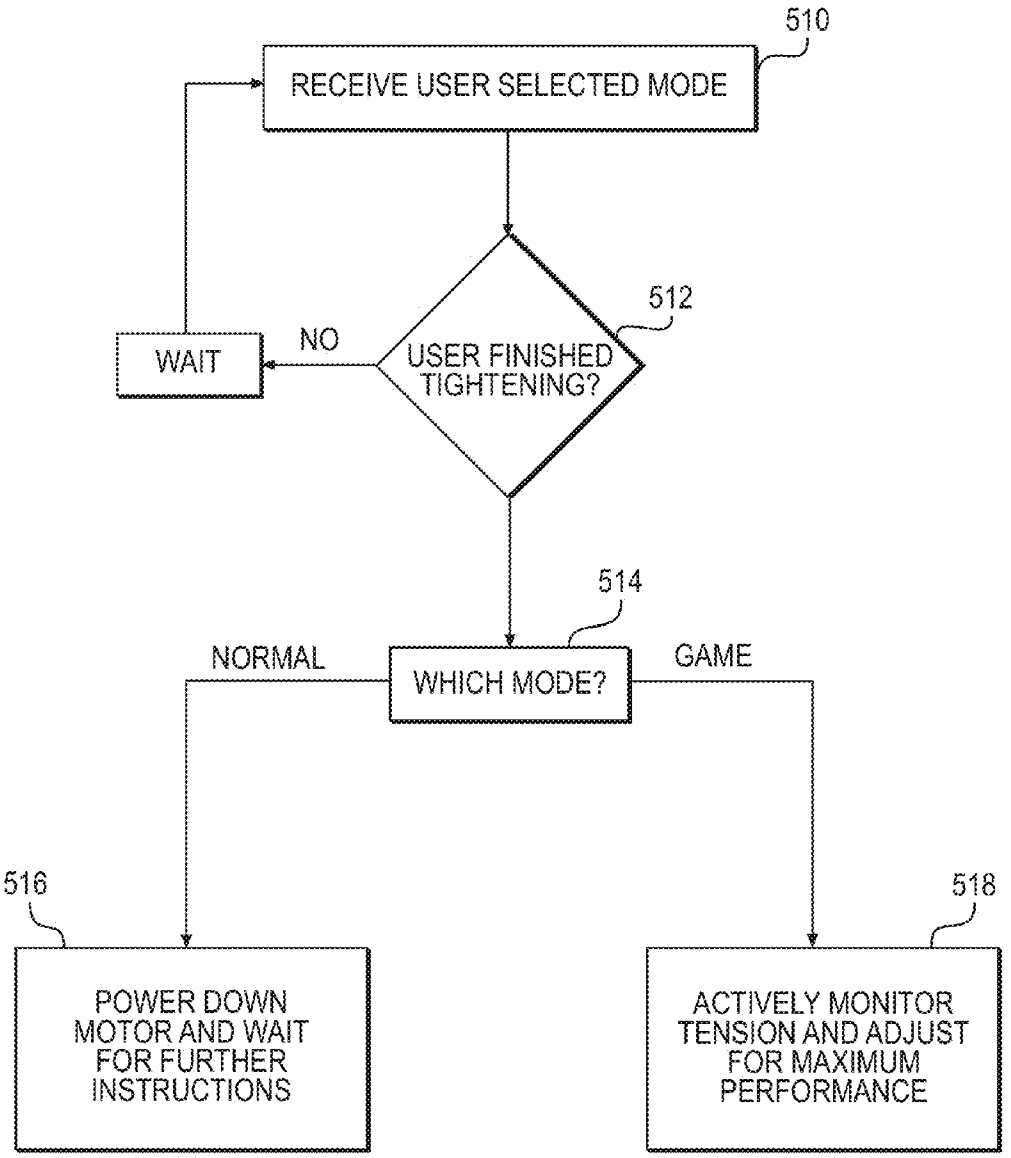

510
RECEIVE USER SELECTED MODE
512
USER FINISHED TIGHTENING?
NO
WAIT
514
WHICH MODE?
NORMAL
GAME
516
POWER DOWN MOTOR AND WAIT FOR FURTHER INSTRUCTIONS
518
ACTIVELY MONITOR TENSION AND ADJUST FOR MAXIMUM PERFORMANCE

FIG. 40

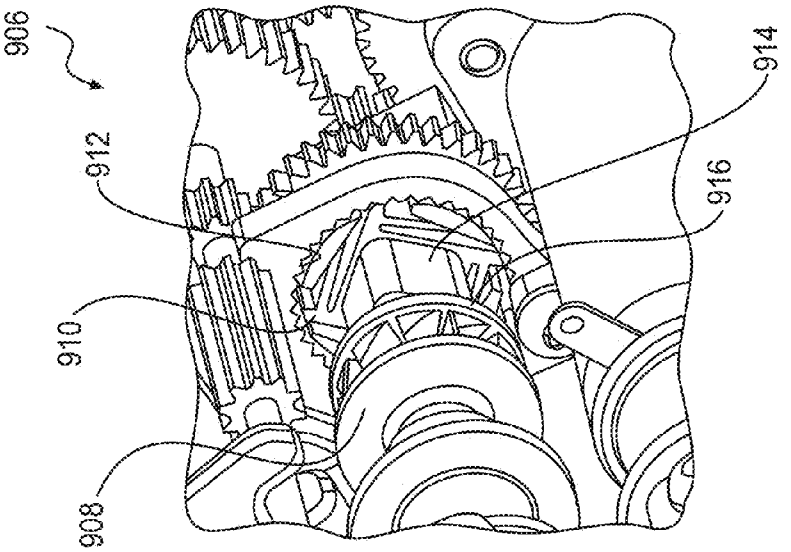


FIG. 42

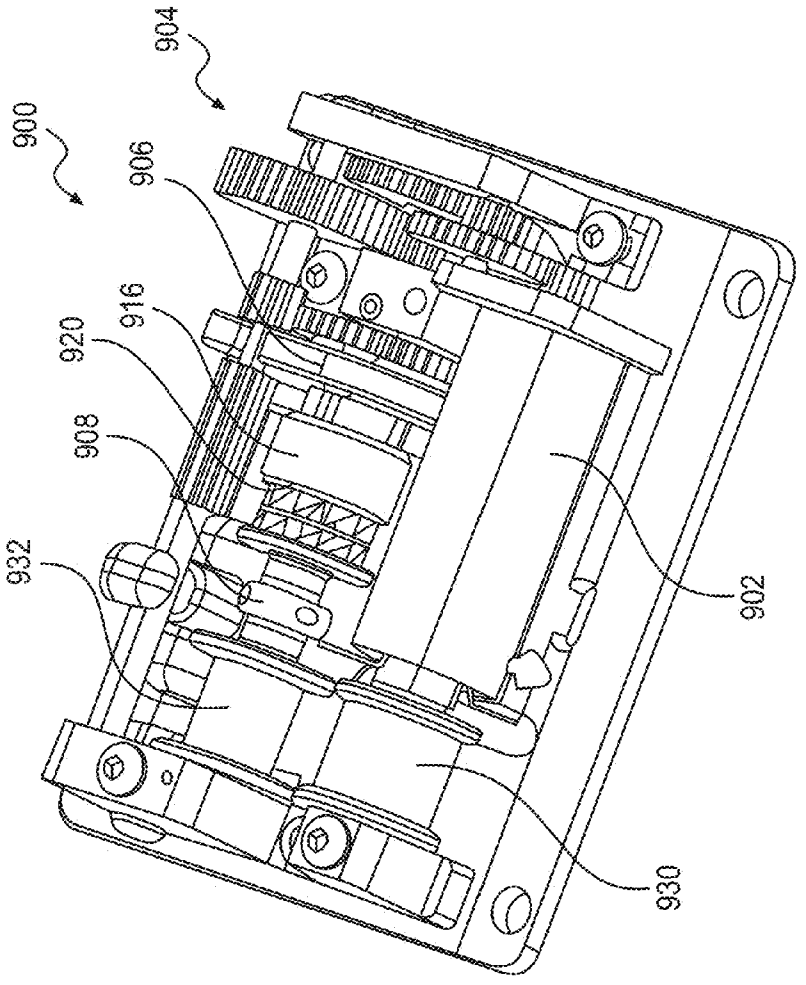


FIG. 41

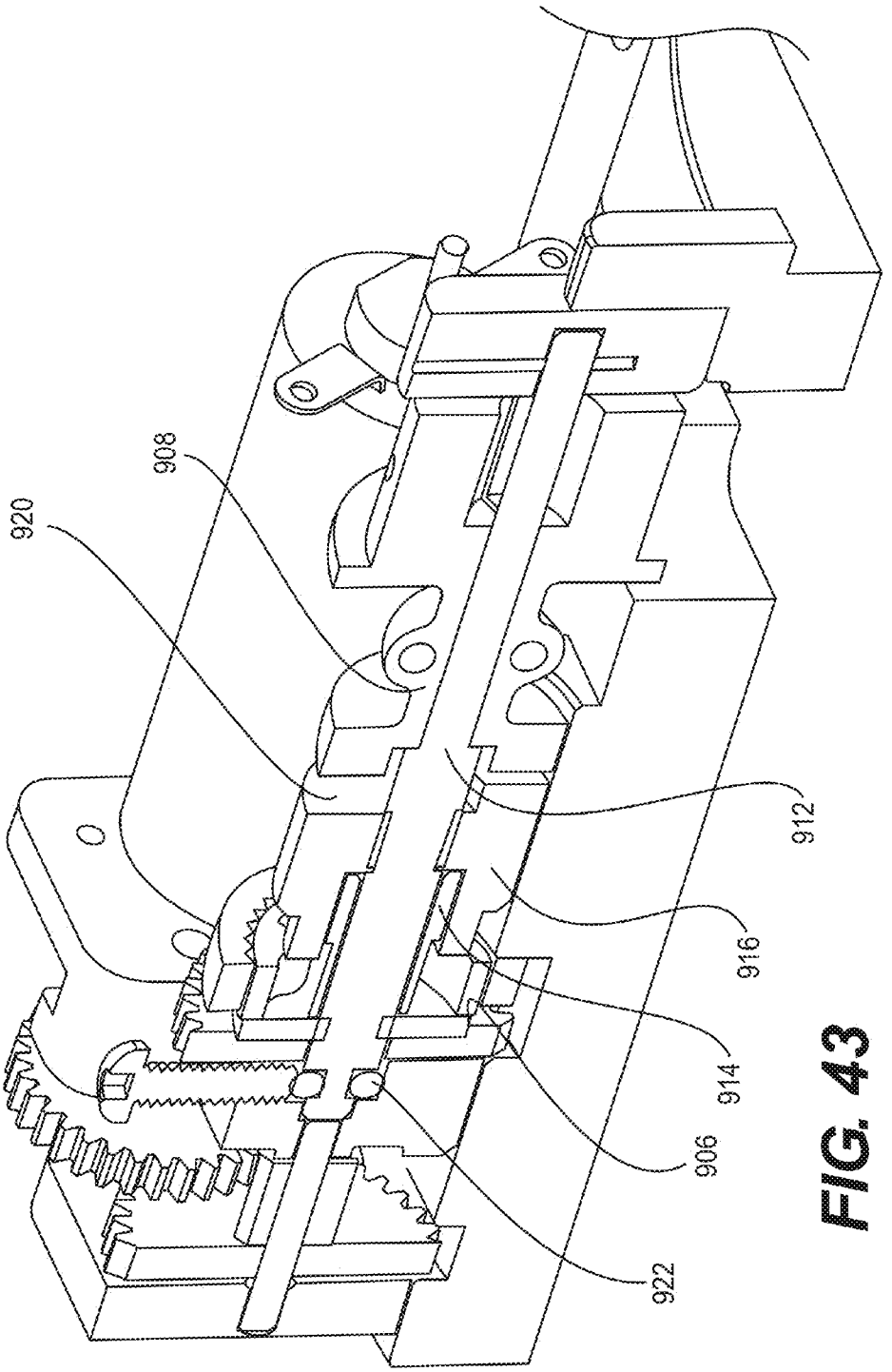


FIG. 43

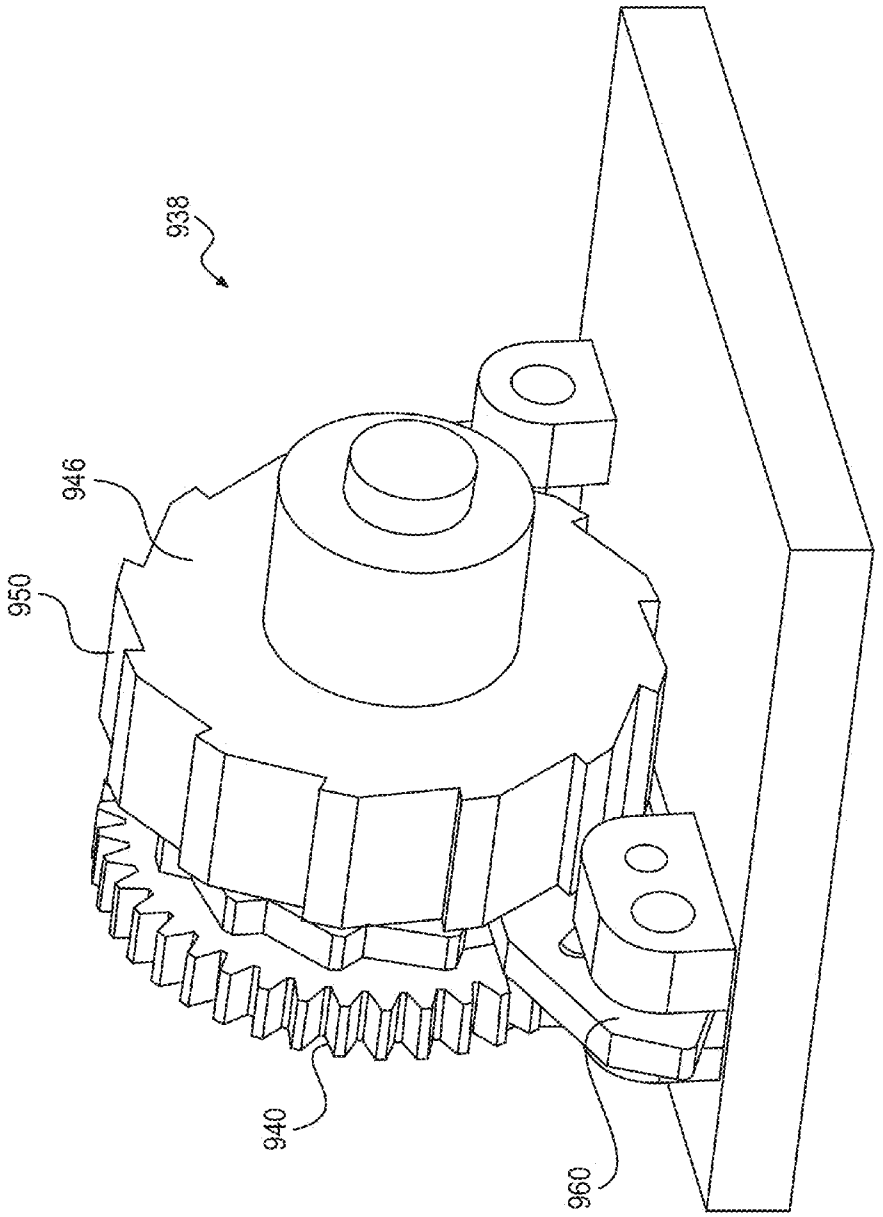


FIG. 44

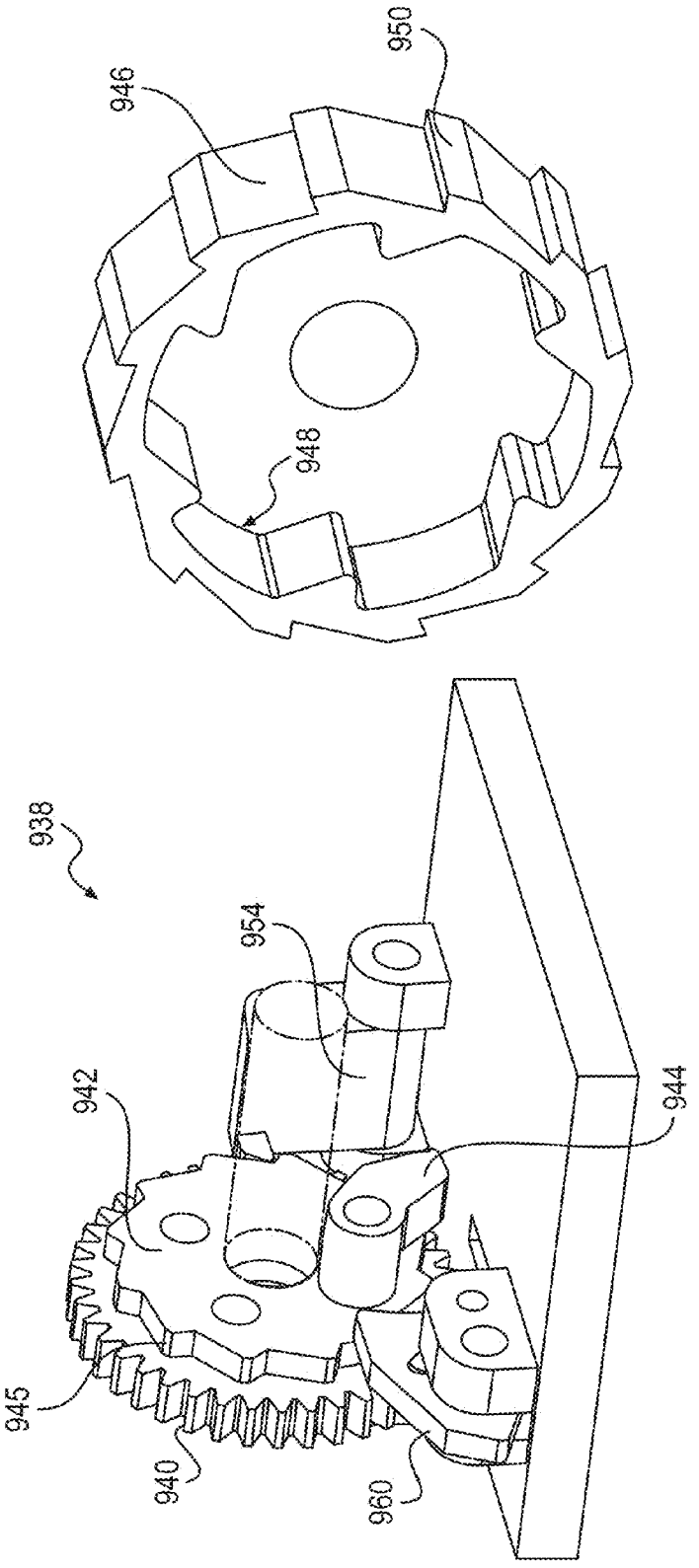


FIG. 45

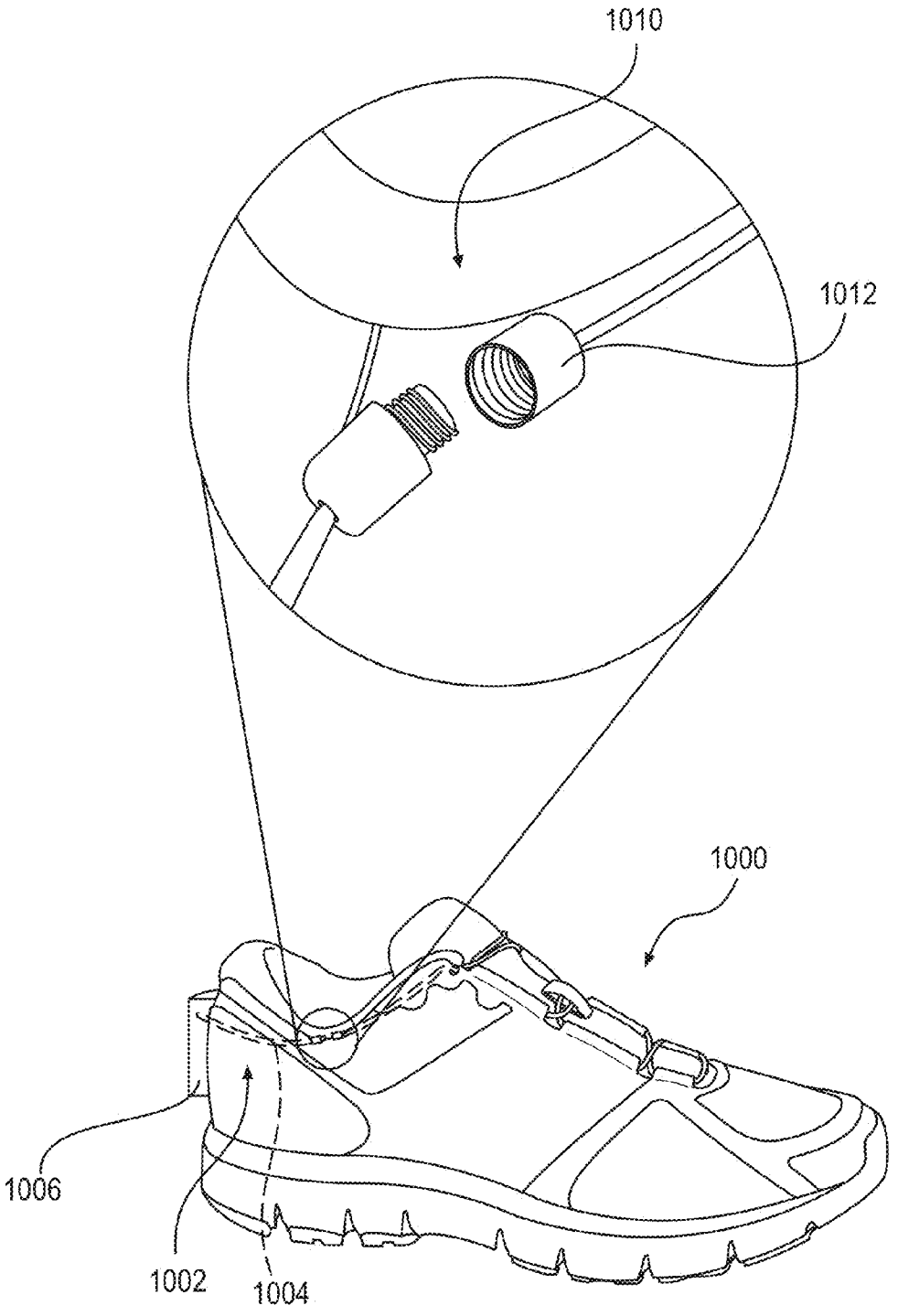


FIG. 46

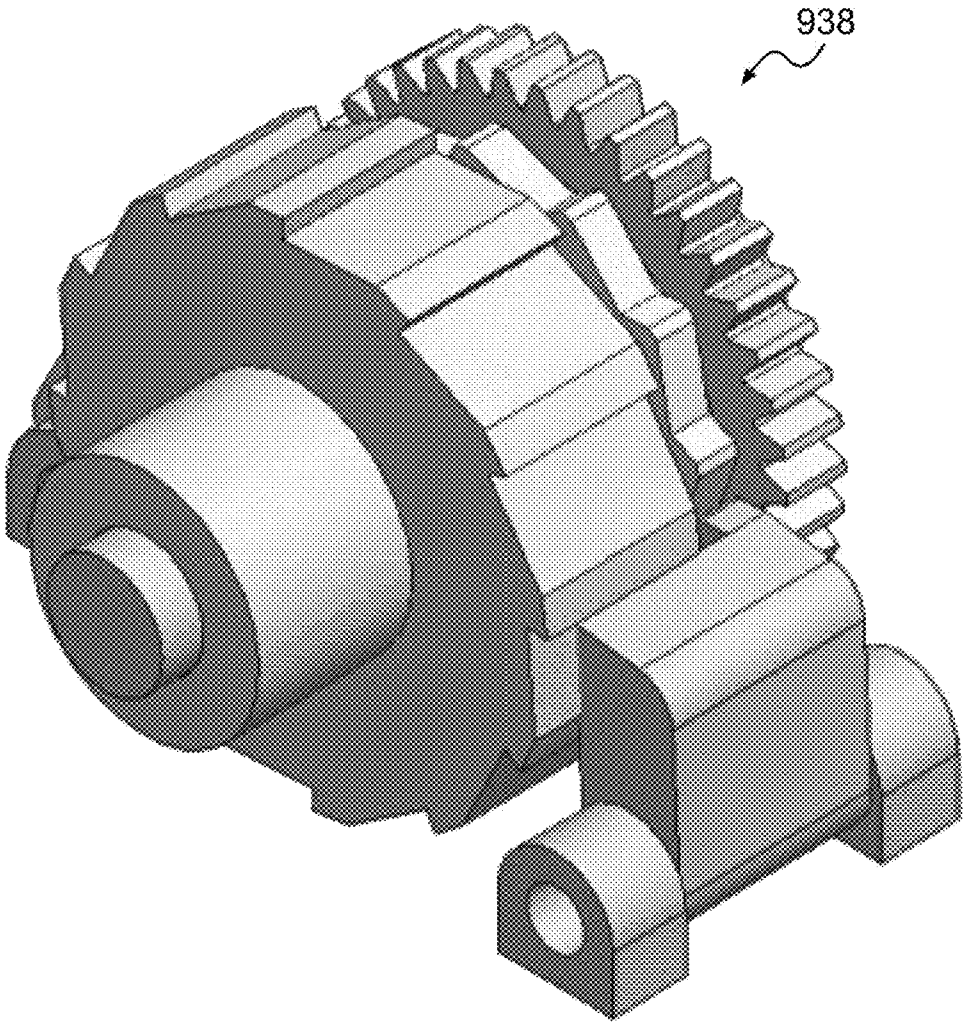


FIG. 47

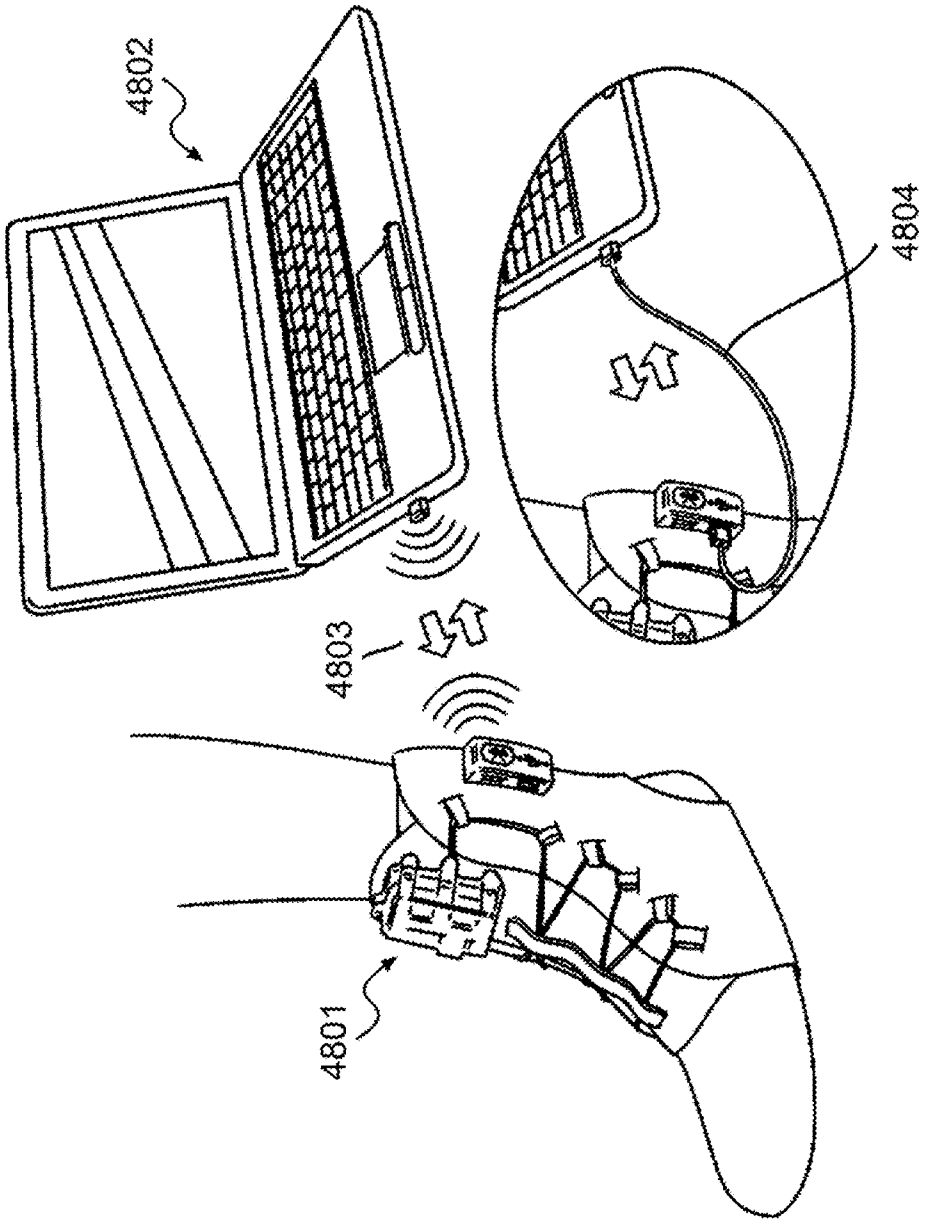


FIG. 48

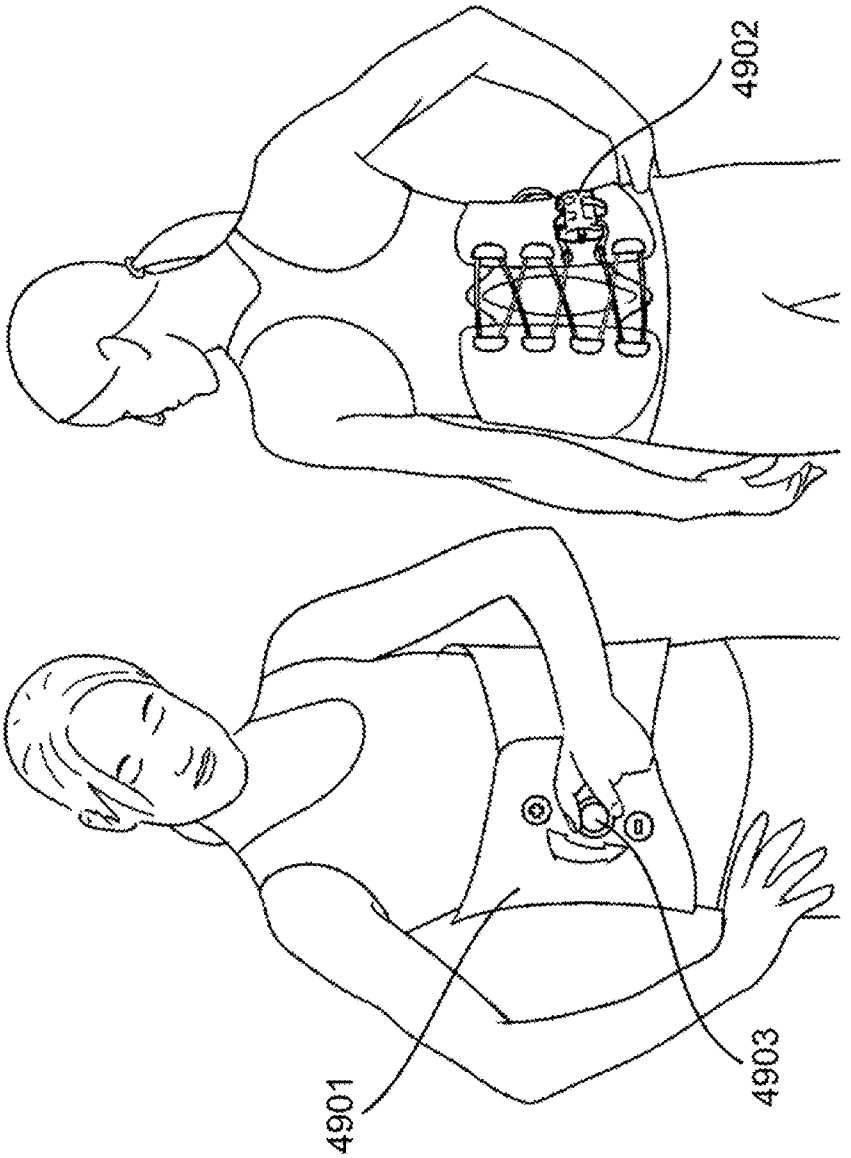


FIG. 49

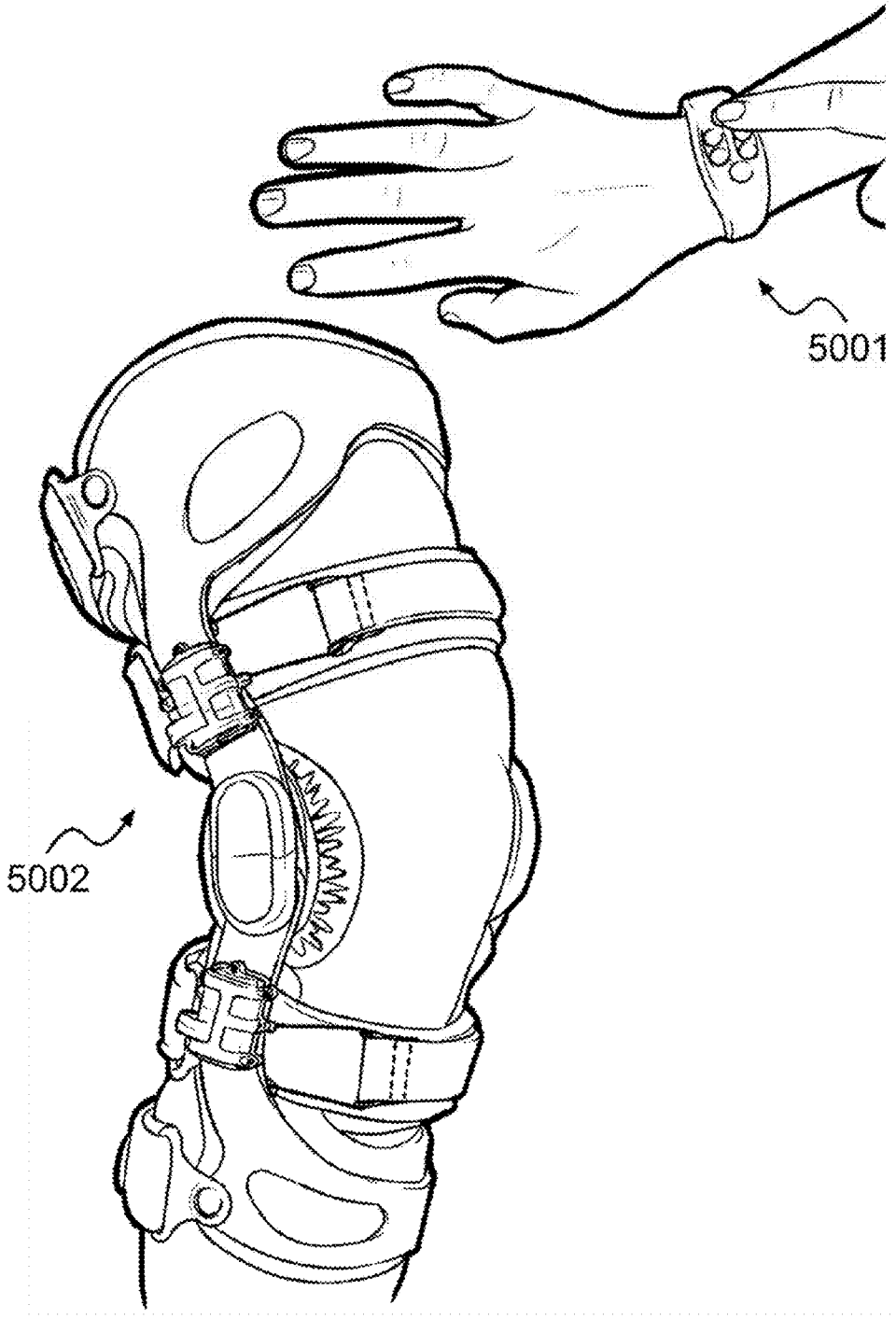


FIG. 50

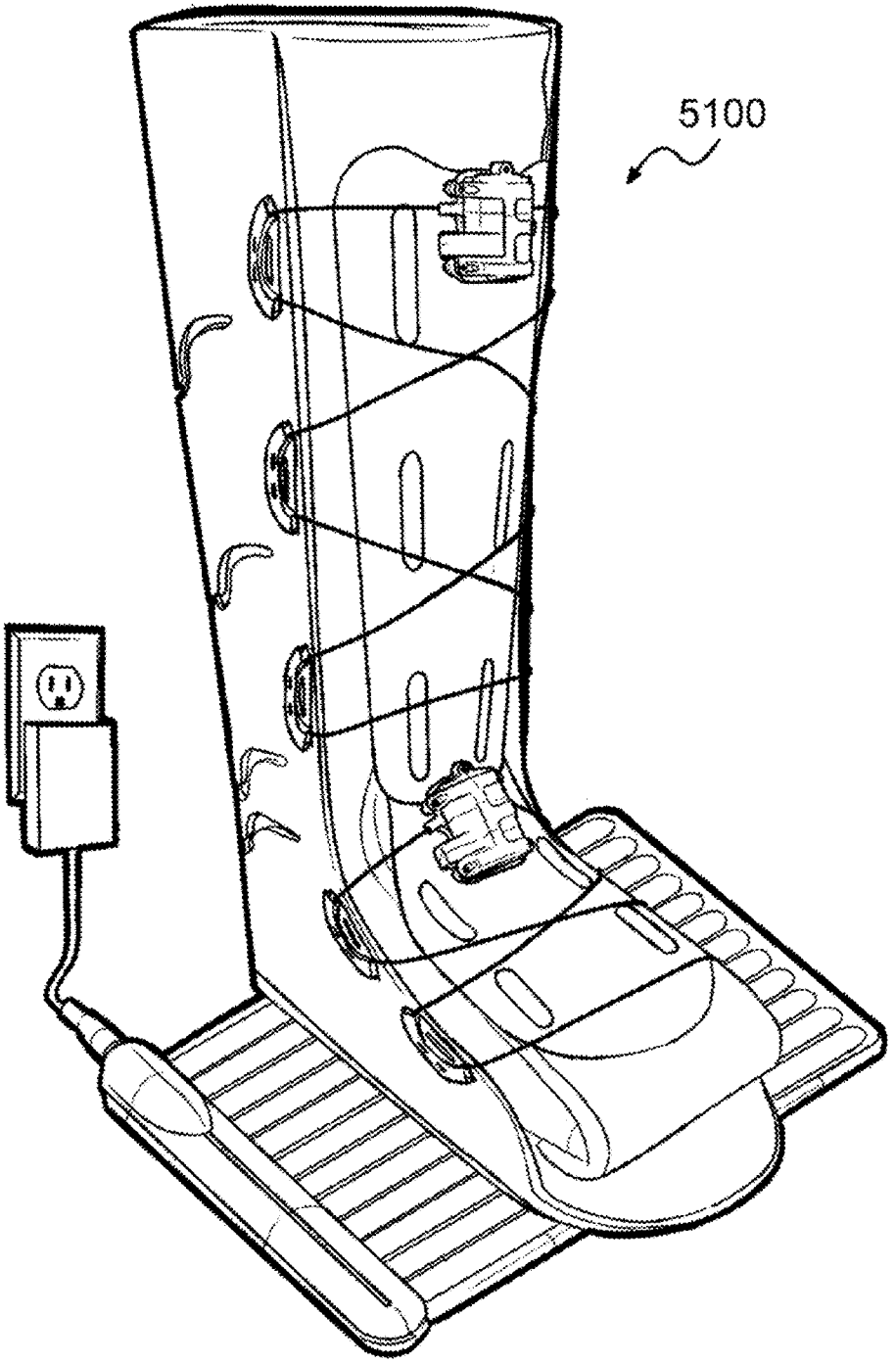


FIG. 51

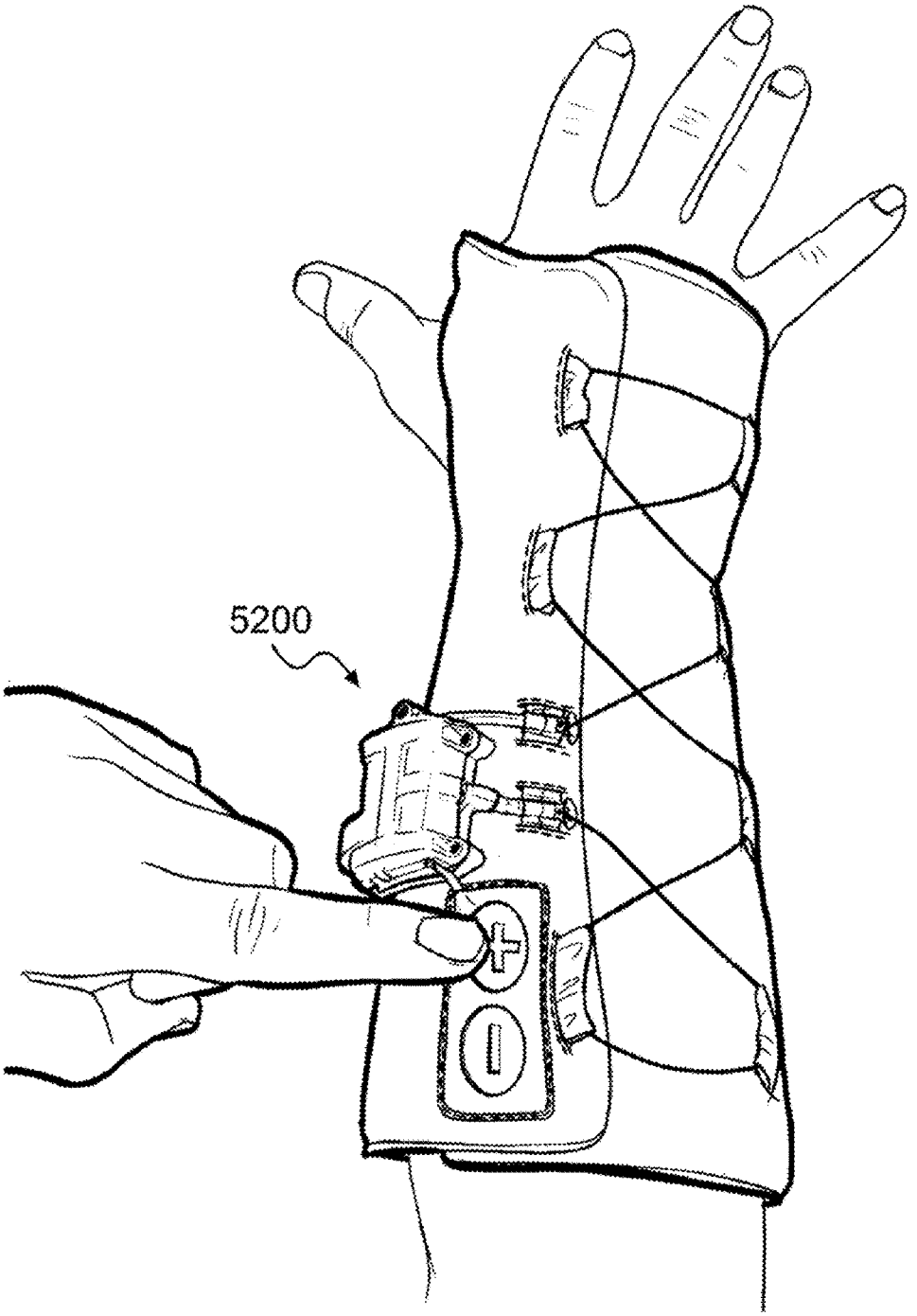


FIG. 52

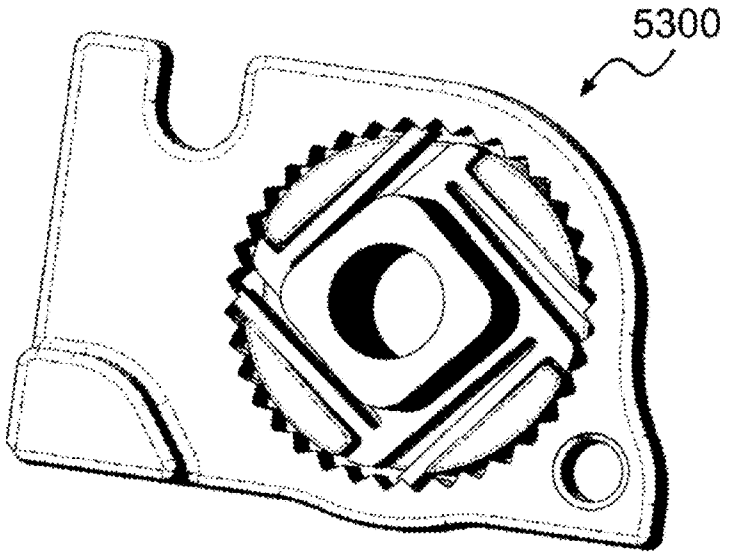


FIG. 53

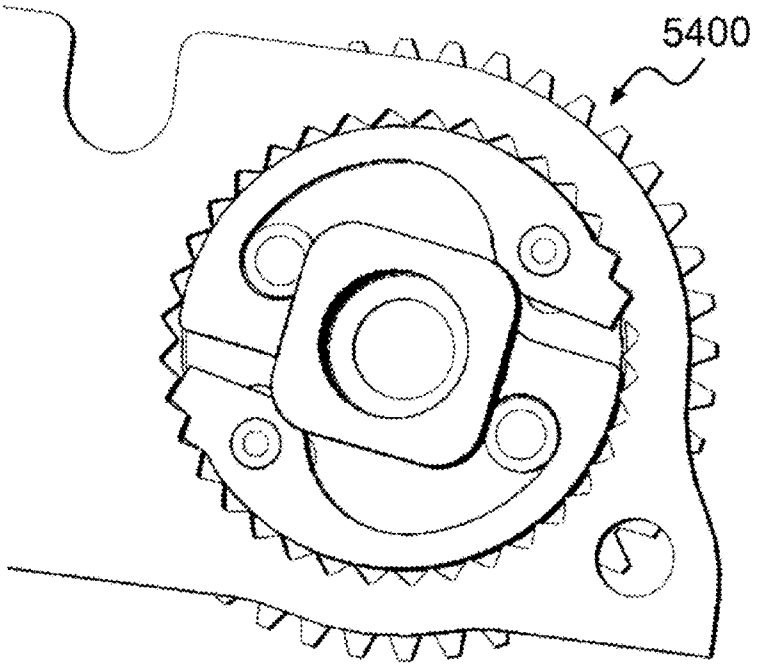


FIG. 54

MOTORIZED TENSIONING SYSTEM WITH SENSORS

RELATED APPLICATION

This application claims the benefit of priority to U.S. Provisional Patent Application Ser. No. 61/695,953, filed on Aug. 31, 2012, which is incorporated by reference herein in its entirety.

BACKGROUND

The present embodiments relate generally to articles of footwear and apparel including tensioning systems.

Articles of footwear generally include two primary elements: an upper and a sole structure. The upper is often formed from a plurality of material elements (e.g., textiles, polymer sheet layers, foam layers, leather, synthetic leather) that are stitched or adhesively bonded together to form a void on the interior of the footwear for comfortably and securely receiving a foot. More particularly, the upper forms a structure that extends over instep and toe areas of the foot, along medial and lateral sides of the foot, and around a heel area of the foot. The upper may also incorporate a lacing system to adjust the fit of the footwear, as well as permitting entry and removal of the foot from the void within the upper. Likewise, some articles of apparel may include various kinds of closure systems for adjusting the fit of the apparel.

SUMMARY

In one aspect, a method of operating a motorized tensioning device in an article of footwear includes sensing information related to a user set tension of a tensioning member used to fasten the article of footwear. The method also includes sensing a current tension of the tensioning member and determining if the current tension is less than the user set tension. The method also includes automatically controlling the motorized tensioning device to increase the tension of the tensioning member to achieve the user set tension when the current tension is less than the user set tension.

In another aspect, an article of footwear includes a tensioning member, a motorized tensioning device for controlling the tension of the tensioning member, at least one sensor for receiving information related to the tension of the tensioning member and a control unit, where the control unit can receive information from the at least one sensor. The control unit operates the motorized tensioning device in a normal operating mode and an active operating mode. The control unit powers down the motorized tensioning device after a target tension has been achieved in the normal operating mode. The control unit monitors the tension of the tensioning member and adjusts the motorized tensioning device to maintain the target tension in the active operating mode.

In another aspect, a footwear tension control system includes an article of footwear including a tensioning member, a motorized tensioning device for adjusting tension in the tensioning member, and a user control system in communication with the motorized tensioning device, where the user control system includes inputs that provide commands to the motorized tensioning device. The user control system includes a footwear selection input, the footwear selection input allowing the user to select between sending commands to a left article of footwear or a right article of footwear. The user control system includes a tighten input. The user control system includes a loosen input.

Other systems, methods, features and advantages of the embodiments will be, or will become, apparent to one of ordinary skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description and this summary, be within the scope of the embodiments, and be protected by the following claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. **1** is a schematic isometric view of an embodiment of an article of footwear with a tensioning system and a remote device for controlling the tensioning system;

FIG. **2** is a schematic view of an embodiment of a remote device running a lacing control application;

FIG. **3** is a schematic view of an embodiment of a foot being inserted into an article and a remote device running a lacing control application;

FIG. **4** is a schematic view of an embodiment of a foot fully inserted into an article and a remote device running a lacing control application;

FIG. **5** is a schematic view of an embodiment of an article being tightened as a remote device sends an incremental tighten command to a tensioning system;

FIG. **6** is a schematic view of an embodiment of an article being loosened as a remote device sends an incremental loosen command to a tensioning system;

FIG. **7** is a schematic view of an embodiment of an article opened to allow a foot to be removed after a remote device has sent an open command to a tensioning system;

FIG. **8** is a schematic isometric view of an embodiment of a motorized tensioning device with an outer cover of the housing unit removed;

FIG. **9** is a schematic exploded isometric view of an embodiment of some components of a motorized tensioning device;

FIG. **10** is a schematic exploded isometric view of an embodiment of a ratcheting assembly;

FIG. **11** is a schematic isometric view of a portion of a motorized tensioning system showing a ratcheting assembly clamped to a spool;

FIG. **12** is a schematic isometric view of an embodiment of a shaft and a rotational control assembly;

FIG. **13** is a schematic isometric view of a portion of a motorized tensioning system showing a rotational control assembly engaging a spool;

FIG. **14** is another schematic isometric view of a portion of the rotational control assembly of FIG. **13**;

FIG. **15** is a schematic isometric view of an embodiment of a spool;

FIG. **16** is a side schematic view of an embodiment of a torque transmitting system;

FIG. **17** is a side schematic view of an embodiment of a torque transmitting system in a fully loosened configuration;

FIG. **18** is a side schematic view of an embodiment of a torque transmitting system in an incremental tightening configuration;

FIG. **19** is a side schematic view of an embodiment of a torque transmitting system in an incremental tighten configuration;

FIG. **20** is a schematic isometric view of a portion of a torque transmitting system as a gear contacts a ratcheting assembly;

FIG. **21** is a schematic isometric view of the portion of torque transmitting system of FIG. **20**, in which the gear, ratcheting assembly and spool are clamped together and the spool is rotated;

FIG. **22** is a side schematic isometric view of a torque transmitting system in an incremental loosen configuration;

FIG. **23** is a schematic isometric view of a torque transmitting system in a first stage of an incremental loosen configuration;

FIG. **24** is a schematic isometric view of a torque transmitting system in a second stage of an incremental loosen configuration;

FIG. **25** is a schematic isometric view of a torque transmitting system in a third stage of an incremental loosen configuration;

FIG. **26** is a schematic side view of an embodiment of a torque transmitting system transitioning to a full loosening configuration;

FIG. **27** is a schematic isometric view of a secondary winding assembly operating while a lace is being wound onto a spool;

FIG. **28** is a schematic isometric view of a secondary winding assembly operating while a lace is being unwound from a spool due to tension on the lace;

FIG. **29** is a schematic isometric view of a secondary winding assembly operating when a lace has developed some slack near the spool;

FIG. **30** is a schematic isometric view of motorized tensioning device including an alternative configuration for a secondary winding assembly;

FIG. **31** is a top down schematic view of a portion of an article including an external heel counter, in which the locations of a motorized tensioning device, a control unit and a battery are indicated schematically;

FIG. **32** is an isometric schematic view of an article of apparel including shoulder pads worn by a user;

FIG. **33** is a schematic enlarged view of an embodiment of a pad configured with a tensioning system;

FIG. **34** is a schematic enlarged view of an embodiment of a pad configured with a tensioning system in which a cable of the tensioning system has been tightened around the pad;

FIG. **35** is a schematic isometric view of an embodiment of a user with an article of apparel having a tensioning device and a remote device for controlling the tensioning device;

FIG. **36** is a schematic isometric view of the user, apparel and remote device of FIG. **35**, in which the user has selected an incremental tighten button and the motorized tensioning device has increased tension around the pad;

FIG. **37** is a schematic isometric view of an embodiment of additional articles of apparel that may be configured with tensioning systems including motorized tensioning devices;

FIG. **38** is a schematic isometric view of an embodiment of an article of footwear including a tensioning system and a remote bracelet configured to control a motorized tensioning device of the tensioning system;

FIG. **39** is a schematic process for automatically controlling tension in an article to maintain an initial tension;

FIG. **40** is a schematic process for automatically controlling tension according to a user selected tensioning mode;

FIG. **41** is a schematic isometric view of an alternative embodiment of a motorized tensioning device;

FIG. **42** is an enlarged isometric view of a load-holding mechanism of the motorized tensioning device of FIG. **41**;

FIG. **43** is a cut-away view of an embodiment of a portion of a motorized tensioning device;

FIG. **44** is an isometric view of another embodiment of a load holding mechanism for a motorized tensioning device;

FIG. **45** is an isometric view of the load holding mechanism of FIG. **44**, in which an output ring has been removed;

FIG. **46** is a schematic isometric view of an embodiment of a manual release mechanism for a tensioning system including a motorized tensioning device;

FIG. **47** is an isometric view of another embodiment of a load holding mechanism for a motorized tensioning device;

FIG. **48** illustrates exemplary communication modes between a tightening system and a computer;

FIG. **49** illustrates an exemplary user interface including a dial for tightening or loosening tension;

FIG. **50** illustrates an exemplary remote interface for tightening a knee brace;

FIG. **51** illustrates an inductive charging configuration for a brace;

FIG. **52** illustrates a user interface for a motorized tightening device, the interface including a conductive panel; and

FIGS. **53-54** illustrate examples of ratcheting mechanisms for different embodiments of a motorized tensioning device.

DETAILED DESCRIPTION

Overview

FIG. **1** illustrates a schematic isometric view of an embodiment of article of footwear **100** that is configured with a tensioning system **150**. In the current embodiment, article of footwear **100**, also referred to hereafter simply as article **100**, is shown in the form of an athletic shoe, such as a running shoe. However, in other embodiments, tensioning system **150** may be used with any other kind of footwear including, but not limited to: hiking boots, soccer shoes, football shoes, sneakers, running shoes, cross-training shoes, rugby shoes, basketball shoes, baseball shoes as well as other kinds of shoes. Moreover, in some embodiments article **100** may be configured for use with various kinds of non-sports related footwear, including, but not limited to: slippers, sandals, high heeled footwear, loafers as well as any other kinds of footwear. As discussed in further detail below, a tensioning system may not be limited to footwear and in other embodiments a tensioning system could be used with various kinds of apparel, including clothing, sportswear, sporting equipment and other kinds of apparel. In still other embodiments, a tensioning system may be used with braces, such as medical braces.

Referring to FIG. **1**, for purposes of reference, article **100** may be divided into forefoot portion **10**, midfoot portion **12** and heel portion **14**. Forefoot portion **10** may be generally associated with the toes and joints connecting the metatarsals with the phalanges. Midfoot portion **12** may be generally associated with the arch of a foot. Likewise, heel portion **14** may be generally associated with the heel of a foot, including the calcaneus bone. It will be understood that forefoot portion **10**, midfoot portion **12** and heel portion **14** are only intended for purposes of description and are not intended to demarcate precise regions of article **100**.

For consistency and convenience, directional adjectives are employed throughout this detailed description corresponding to the illustrated embodiments. The term "longitudinal" as used throughout this detailed description and in the claims refers to a direction extending a length of a component. Also, the term "lateral" as used throughout this detailed description and in the claims refers to a direction extending a

width of a component. Furthermore, the term "vertical" as used throughout this detailed description and in the claims refers to a direction that is perpendicular to both the longitudinal and lateral directions. It will be understood that each of these directional adjectives may be applied to various components shown in the embodiments, including article **100**, as well as components of tensioning system **120**.

Article **100** may include upper **102** and sole structure **104**. Generally, upper **102** may be any type of upper. In particular, upper **102** may have any design, shape, size and/or color. For example, in embodiments where article **100** is a basketball shoe, upper **102** could be a high top upper that is shaped to provide high support on an ankle. In embodiments where article **100** is a running shoe, upper **102** could be a low top upper.

In some embodiments, sole structure **104** may be configured to provide traction for article **100**. In addition to providing traction, sole structure **104** may attenuate ground reaction forces when compressed between the foot and the ground during walking, running or other ambulatory activities. The configuration of sole structure **104** may vary significantly in different embodiments to include a variety of conventional or non-conventional structures. In some cases, the configuration of sole structure **104** can be configured according to one or more types of ground surfaces on which sole structure **104** may be used. Examples of ground surfaces include, but are not limited to: natural turf, synthetic turf, dirt, as well as other surfaces.

In different embodiments, sole structure **104** may include different components. For example, sole structure **104** may include an outsole, a midsole, and/or an insole. In addition, in some cases, sole structure **104** can include one or more cleat members or traction elements that are configured to increase traction with a ground surface.

In some embodiments, sole structure **104** may be joined with upper **102**. In some cases, upper **102** is configured to wrap around a foot and secure sole structure **104** to the foot. In some cases, upper **102** may include opening **130** that provides access to an interior cavity of article **100**.

A tensioning system may include a tensioning member. The term "tensioning member" as used throughout this detailed description and in the claims refers to any component that has a generally elongated shape and high tensile strength. In some cases, a tensioning member could also have a generally low elasticity. Examples of different tensioning members include, but are not limited to: laces, cables, straps and cords. In some cases, tensioning members may be used to fasten and/or tighten an article, including articles of clothing and/or footwear. In other cases, tensioning members may be used to apply tension at a predetermined location for purposes of actuating some components or system.

Tensioning system **150** may comprise various components and systems for adjusting the size of opening **130** and thereby tightening (or loosening) upper **102** around a wearer's foot. In some embodiments, tensioning system **150** may comprise lace **152** as well as motorized tensioning device **160**. Lace **152** may be configured to pass through various different lacing guides **154**, which may be further associated with the edges of throat opening **132**. In some cases, lacing guides **154** may provide a similar function to traditional eyelets on uppers. In particular, as lace **152** is pulled or tensioned, throat opening **132** may generally constrict so that upper **102** is tightened around a foot.

The arrangement of lacing guides **154** in this embodiment is only intended to be exemplary and it will be understood that other embodiments are not limited to a particular configuration for lacing guides **154**. Furthermore, the particular types of lacing guides **154** illustrated in the embodiments are also exemplary and other embodiments may incorporate any other kinds of lacing guides or similar lacing provisions. In some other embodiments, for example, lace **154** could be inserted through traditional eyelets. Some examples of lace guiding provisions that may be incorporated into the embodiments are disclosed in Cotterman et al., U.S. Patent Application Publication Number 2012/0000091, now U.S. application Ser. No. 13/174,527, filed Jun. 30, 2011, and entitled "Lace Guide", which is hereby incorporated by reference in its entirety. Additional examples are disclosed in Goodman et al., U.S. Patent Application Publication Number 2011/0266384, now U.S. application Ser. No. 13/098,276, filed Apr. 29, 2011 and entitled "Reel Based Lacing System" (the "Reel Based Lacing Application"), which is hereby incorporated by reference in its entirety. Still additional examples of lace guides are disclosed in Kerns et al., U.S. Patent Application Publication Number 2011/0225843, now U.S. application Ser. No. 13/011,707, filed Jan. 21, 2011 and entitled "Guides For Lacing Systems", which is hereby incorporated by reference in its entirety.

Lace **152** may comprise any type of type of lacing material known in the art. Examples of lace that may be used include cables or fibers having a low modulus of elasticity as well as a high tensile strength. A lace may comprise a single strand of material, or can comprise multiple strands of material. An exemplary material for the lace is SPECTRA™, manufactured by Honeywell of Morris Township N.J., although other kinds of extended chain, high modulus polyethylene fiber materials can also be used as a lace. Still further exemplary properties of a lace can be found in the Reel Based Lacing Application mentioned above.

In some embodiments, lace **152** may be passed through lacing guides **154** and may pass through internal channels (not shown) within upper **102** after entering channel openings **156** that are above lacing guides **156**. In some embodiments, the internal channels extend around the sides of upper **102** and guide the lace towards motorized tensioning device **160**, which may be mounted on heel portion **14** of upper **102**. In some cases, motorized tensioning device **160** may include provisions for receiving portions of lace **152**. In some cases, end portions of lace **152** exit internal channels of upper **102** and pass through apertures in a housing unit **212** of motorized tensioning device **160**.

Motorized tensioning device **160** may be configured to automatically apply tension to lace **152** for purposes of tightening and loosening upper **102**. As described in further detail below, motorized tensioning device **160** may include provisions for winding lace **152** onto, and unwinding lace **152** from, a spool internal to motorized tensioning device **160**. Moreover, the provisions may include an electric motor that automatically winds and unwinds the spool in response to various inputs or controls.

Provisions for mounting motorized tensioning device **160** to upper **102** can vary in different embodiments. In some cases, motorized tensioning device **160** may be removably attached, so that motorized tensioning system **160** can be easily removed by a user and modified (for example, when a lace must be changed). Examples of provisions for removably attaching motorized tensioning system **160** to upper **102** are discussed in detail later. In other cases, motorized lacing device **160** could be permanently attached to upper **102**. In one embodiment, for example, an external harness (not shown) may be used to mount motorized tensioning system **160** to upper **102** at heel portion **14**.

In some embodiments, motorized tensioning device **160** may communicate with remote device **170**. In some cases,

motorized tensioning device **160** may receive operating instructions from remote device **170**. For example, motorized tensioning device **160** may receive instructions to apply increased tension to lace **152** by winding the spool. In some cases, remote device **170** may be capable of receiving information from motorized tensioning device **160**. For example, remote device **170** could receive information related to the current tension in lace **152** and/or other sensed information. As discussed below in reference to FIG. **2**, remote device **170** may function as a remote control that may be used by the wearer to operate tensioning system **150**.

In one embodiment, remote device **170** comprises a mobile phone, such as the iPhone made by Apple, Inc. In other embodiments, any other kinds of mobile phones could also be used including smartphones. In other embodiments, any portable electronic devices could be used including, but not limited to: personal digital assistants, digital music players, tablet computers, laptop computers, ultrabook computers as well as any other kinds of portable electronic devices. In still other embodiments, any other kinds of remote devices could be used including remote devices specifically designed for controlling motorized tensioning device **160**. In another embodiment, discussed in detail below, remote device **170** could comprise a bracelet, wristband and/or armband that is worn by a user and specifically designed for communicating with motorized tensioning device **160**. The type of remote device could be selected according to software and hardware requirements, ease of mobility, manufacturing expenses, as well as possibly other factors. In some embodiments, motorized tightening device **160** may communicate with multiple remote devices. For example, a user may use a mobile device, such as an iPhone, at home to identify and set preferred tension settings, and another remote device with more rudimentary controls might then be used to issue commands to motorized tightening device **160**, such as with a bracelet, wristband and/or armband while playing sports. For example, a bracelet might allow a user to recall a set tension and adjust it, but not set a new tension for later recall. In some embodiments, such as where motorized tightening device **160** is used for a medical brace, a physician may be provided with fewer controls for the medical brace. For example, the wearer may be provided with a remote device that allows a full range of commands and/or tensions for adjusting fit or performance, but the wearer of that brace may be provided with a remote device that is not configured to issue all of the commands available with the physician's remote device and/or allows a more limited range of tension adjustment, such as for improving comfort without disturbing the overall fit of the brace.

As already mentioned, remote device **170** may communicate with motorized tightening device **160** (or indirectly with motorized tightening device **160** via a secondary device, such as a separate control unit). Examples of different communication methods include, but are not limited to: wireless networks such as personal area networks (e.g., Blutetooth) and local area networks (e.g., Wi-Fi) as well as any kinds of RF based methods known in the art. In some embodiments, infrared light may be used for wireless communication. Although the illustrated embodiments detail a remote device **170** that communicates wirelessly with motorized tensioning system **160**, in other embodiments remote device **170** and motorized tensioning system **160** may be physically connected and communicate through one or more wires.

For purposes of clarity, a single article of footwear is shown in the embodiments. However, it will be understood that remote device **170** may be configured to operate a corresponding article of footwear which also includes a similar tensioning system (e.g., a pair of footwear each having a tensioning system). As described below, remote device **170** may be used to operate each the tensioning systems of each article independently of one another.

FIG. **2** illustrates a schematic view of an embodiment of remote device **170**, including a schematic of an example user interface for controlling tensioning system **150**. In some embodiments, remote device **170** may be capable of running a lacing control software application **180**, hereafter referred to simply as application **180**. In embodiments where remote device **170** is a mobile phone (or similar digital device) capable of running mobile software applications, application **180** may be downloaded by a user from a third party online store or website. Such a mobile phone (or similar digital device) may include a touch screen LCD device which may be used by application **180** for input and output interaction with a user. In some embodiments, a touch screen LCD or non-touch screen LCD may be used for output display only.

Application **180** may display and respond to user interaction with a plurality of control buttons **182**, and initiate control commands in response to such interaction. Example control commands may include, but are not limited to, left/right shoe selection, incremental tighten, incremental loosen, open/fully loosen, store tension, and recall/restore tension. In the exemplary embodiment of FIG. **2**, these control buttons include a first button **191** and a second button **192**, which are respectively used to select the left or right shoe that will receive and respond to the control commands. In some embodiments, either first button **191** or second button **192** may be selected, but both may not be selected simultaneously. In other cases, it may be possible to select both first button **191** and second button **192** simultaneously, to allow a user to tighten, loosen, or open both shoes simultaneously. In addition, application **180** may include third button **193** for initiating an "incremental tighten" command, a fourth button **194** for initiating an "incremental loosen" command and a fifth button **195** for initiating an "open" (or fully loosen) command. Optionally, some embodiments could include a "fully tighten" command that would tighten the footwear until a predetermined threshold is achieved (for example, a threshold pressure, winding distance, etc.).

In some embodiments, a shoe, article, or other item may include more than one motorized tightening device **160**. In such embodiments, each motorized tightening device **160** may include wireless communication hardware for separately communicating with a remote device **170**, or a single wireless communication device may be provided for common use by multiple motorized tightening devices **160**. For such embodiments, remote device **170** may be configured, such as with application **180**, to provide additional buttons or other controls to individually adjust plural motorized tightening devices **160** on a single article. For example, button **191** illustrated in FIG. **2** could be subdivided into a top region and lower region which are separately responsive to user interaction. By use of these regions, one of two motorized tightening devices **160** could be selected for tension adjustment via buttons **193**, **194**, and **195**. In another example, additional buttons like buttons **193** and **194** could be displayed at the same time by application **180**, allowing for more rapid adjustment of multiple motorized tightening devices **160**.

Application **180** may also include provisions for storing and using preferred tension settings. For example, sixth button **196** and seventh button **197** may be used to initiate a "store current tension" command and a "return to stored tension" command, respectively. In some cases, the tension values could be stored at the remote device, while in other cases the tension values could be stored in internal memory of a control board for the motorized tensioning device **160**. Still other

embodiments could include provisions for storing multiple tension settings. For example, a user may prefer a tighter fit for playing sports and a looser fit for casual activities. In such cases, remote device **170** may allow a user to store two or more tension settings, corresponding to at least two different lace tension preferences. In some embodiments, sixth button **196** may cause the tension setting for a single, currently selected, motorized tightening device **160** to be stored, and in some embodiments sixth button **196** may cause the tension settings for multiple motorized tightening devices **160** to be stored in a single action. Those skilled in the art appreciate that storage or recall of tensions for multiple motorized tightening devices **160**, whether part of a single item of apparel or multiple items, such as a pair of shoes, may be performed with a single command issued by a remote device **170** or with a series of control commands, such as by issuing separate control commands to each motorized tightening device **160** and/or item of apparel.

In some embodiments, application **180** and/or remote device **170** may be configured to selectively control individual items or individual sets of items, such as a pair of shoes, from among multiple items or sets of items within communication range of remote device **170**. For example, application **180** may be configured to enumerate items by unique identifiers assigned to each item, display the enumerated items to a user, and receive an input selecting an item. In another example, an application **180** may be paired via BlueTooth with a particular item or set of items. In another example, a remote device without an LCD display may include a control button that may be pressed, repeatedly if needed, to select a desired item, and the item may include an LED which is illuminated when it is in wireless communication with the remote device.

The embodiments are not limited to a particular user interface or application for remotely operating motorized tensioning device **160**. The embodiments here are intended to be exemplary, and other embodiments could incorporate any additional control buttons, interface designs and software applications. As one example, some embodiments may not include provisions for selecting the shoe to be controlled, and instead could utilize two sets of control buttons, where each set corresponds to either the left or right shoe. The control buttons for initiating various operating commands can be selected according to various factors including: ease of use, aesthetic preferences of the designer, software design costs, operating properties of the motorized tensioning device **160** as well as possibly other factors.

Throughout the detailed description and in the claims, various operating modes, or configurations, of a tensioning system are described. These operating modes may refer to states of the tensioning system itself, as well as to the operating modes of individual subsystems and/or components of the tensioning system. Exemplary modes include an "incremental tighten mode", an "incremental loosen mode" and a "fully loosen" mode. The latter two modes may also be referred to as an "incremental release mode" and a "full release mode". In the incremental tighten mode, motorized tightening device **160** may operate in a manner that incrementally (or gradually) tightens, or increases the tension of, lace **152**. In the incremental loosen mode, motorized tightening device **160** may operate in a manner that incrementally (or gradually) loosens, or releases tension in, lace **152**. As discussed further below, the incremental tighten mode and the incremental loosen mode may tighten and loosen a lace in discrete steps or continuously. In the full release mode, motorized tightening device **160** may operate in a manner so that tension applied to the lace by the system is substantially reduced to a level where the user can easily remove his or her foot from the article. This is in contrast to the incremental release mode, where the system operates to achieve a lower tension for the lace relative to the current tension, but not necessarily to completely remove tension from the laces. Moreover, while the full release mode may be utilized to quickly release lace tension so the user can remove the article, the incremental release mode may be utilized to make minor adjustments to the lace tension as a user searches for the desired amount of tension. Although the embodiments describe three possible modes of operation (and associated control commands), other operating modes may also be possible. For example, some embodiments could incorporated a fully tighten operating mode where motorized tightening device **160** continues to tighten lace **152** until a predetermined tension has been achieved.

FIGS. **3** through **7** illustrate schematic views of an embodiment of article **100** being tightened and loosened during different operating modes of tensioning system **150**. Each figure also shows a schematic view of remote device **170**, including the particular control button used to initiate each operating mode.

FIG. **3** shows article **100** is in a fully opened state just prior to the entry of foot **200**. In this state, lace **152** may be loose enough to allow a user to insert his or her foot into opening **130**. Referring next to FIG. **4**, foot **200** is inserted into article **100**, which remains in the fully opened state. Referring next to FIG. **5**, an incremental tighten command has been sent to motorized tensioning device **160** by pressing third button **193** of remote device **170**. This command causes motorized tensioning device **160** to enter an incremental tighten mode. At this point, the tension of lace **152** is increased to tighten upper **102** around foot **200**. In particular, lace **152** is drawn into motorized tensioning device **160**, which pulls on the portions of lace **152** disposed adjacent throat opening **132** and thus constricts throat opening **132**. In some cases, this incremental tightening can occur in discrete steps so that each time the wearer presses third button **193**, lace **152** is taken up by a predetermined amount (for example by rotating a spool within motorized tensioning device **160** through a predetermined angle). In other cases, this incremental tightening can occur in a continuous manner, as long as the wearer continues to touch third button **193**. In some cases, the speed of tightening can be set so that the system does not overshoot a preferred level of tightness (i.e., the system doesn't move between not tight enough and overly tight too quickly) while also being large enough to avoid overly long times for fully tightening article **100**.

FIGS. **6** and **7** illustrate schematic views of two different operating modes where lace **152** may be loosened. Referring first to FIG. **6**, a wearer can press fourth button **194** to initiate an incremental loosen command in tensioning system **150**. Upon receiving the incremental loosen command, motorized tensioning device **160** may operate in an incremental loosen mode, in which lace **152** is released from motorized tensioning device **160** (i.e., sections of lace **152** exit from motorized tensioning device **160**). This relaxes some of the tension in lace **152** and allows throat opening **132** to partially expand. In some cases, this incremental loosening can occur in discrete steps so that each time the wearer presses fourth button **194**, lace **152** is let out up by a predetermined amount (for example by rotating a spool within motorized tensioning device **160** through a predetermined angle). In other cases, this incremental loosening can occur in a continuous manner, as long as the wearer continues to touch fourth button **194**. In some cases, the speed of loosening can be set so that the system does not overshoot a preferred level of tightness (i.e., the

system doesn't move between too tight and not tight enough too quickly) while also being large enough to avoid overly long times for fully loosening article **100**. With this arrangement, a wearer can continue increasing and decreasing the tension of lace **152** (using the incremental tighten and incremental loosen modes) until a preferred level of tightness for upper **102** is achieved.

Referring next to FIG. **7**, a wearer can press fifth button **195** to initiate an open, or fully loosen, command in tensioning system **150**. In contrast to the incremental loosen command, the open command may be used to quickly relieve all (or most of) tension in lace **152** so that a user can quickly remove article **100**. Thus, upon receiving the open command, motorized tensioning device **160** operates in a fully loosen mode. In this mode, motorized tensioning device operates to let out enough of lace **152** so that substantially all tension is removed from lace **152**. In some cases, this may be achieved by continuously monitoring tension in lace **152** (for example, using sensors) and letting out lace **152** until the level of tension is below a threshold tension. In other cases, this may be achieved by letting out a predetermined length of lace **152** known to correspond approximately to the amount needed to achieve a fully loosened state for tensioning system **150**. As seen in FIG. **7**, with tensioning system **150** in the open state, foot **200** can be easily and comfortably removed from footwear **100**.

FIGS. **8** and **9** illustrate an isometric view and isometric exploded view, respectively, of an embodiment of the internal components of motorized tensioning device **160**. Referring first to FIG. **8**, the components are shown within a portion of housing unit **212**. Housing unit **212** may further include an inner housing portion **216** and an outer housing portion **218**. Outer housing portion **218** may include a base panel **210** as well as an outer cover **214** (shown in FIG. **1**), and generally provides a protective outer covering for components of motorized tensioning device **160**. Inner housing portion **216** may be shaped to support components of motorized tensioning device **160**. In some cases portions of inner housing portion **216** function to limit the mobility of some components, as discussed in detail below.

Referring now to FIGS. **8** and **9**, in some embodiments, motorized tensioning system **160** may comprise motor **220** (shown schematically in FIG. **9**). In some embodiments, motor **220** may be an electric motor. However, in other embodiments, motor **220** could comprise any kind of non-electric motor known in the art. Examples of different motors that can be used include, but are not limited to: DC motors (such as permanent-magnet motors, brushed DC motors, brushless DC motors, switched reluctance motors, etc.), AC motors (such as motors with sliding rotors, synchronous electrical motors, asynchronous electrical motors, induction motors, etc.), universal motors, stepper motors, piezoelectric motors, as well as any other kinds of motors known in the art. Motor **220** may further include a motor crankshaft **222** that can be used to drive one or more components of motorized tensioning system **160**. Provisions for powering motor **220**, including various kinds of batteries, are discussed in detail below.

In some embodiments, motorized tensioning system **160** can include provisions for reducing the output speed of, and increasing the torque generated by, motor **220**. In some embodiments, motorized tensioning system **160** can include one or more gear reduction assemblies and/or gear reduction systems. In some embodiments, motorized tensioning system **160** may include a single gear reduction assembly. In other embodiments, motorized tensioning system **160** may include two or more gear reduction assemblies. In one embodiment, motorized tensioning system **160** includes first gear reduction assembly **230** and second gear reduction assembly **232**, which may be collectively referred to as gear reduction system **228**. First gear reduction assembly **230** may be an in-line spur gear reduction assembly that is generally aligned with motor **220** and/or crankshaft **222**. In contrast, second gear reduction assembly **232** may provide additional gear reduction that extends in a generally perpendicular direction to the orientation of crankshaft **222**. With respect to housing unit **212**, first gear reduction assembly **230** may extend in a longitudinal direction of housing unit **212** while second gear reduction assembly **232** may extend in a lateral (or horizontal) direction of housing unit **212**. By using a combination of in-line gears and horizontally spaced gears, relative to the orientation of crankshaft **222**, motor **220** can be arranged in parallel with a spool and corresponding spool shaft (as discussed in further detail below). This arrangement may reduce the longitudinal space required to fit all the components of motorized tensioning device **160** within housing unit **212**.

Each gear reduction assembly can comprise one or more gears. In the exemplary embodiment, first gear reduction assembly **230** comprises one or more in-line spur gears. Moreover, first gear reduction assembly **230** may be driven by crankshaft **222** and itself drives a first gear **234** of second gear reduction assembly **232**.

In one embodiment, second gear reduction assembly **232** may be configured with 4 stages of spur gears, including a first gear **234**, a second gear **235**, a third gear **236** and a fourth gear **237**. In this embodiment, fourth gear **237** acts as a clamping gear for turning additional components of motorized tensioning device **160**, as described in further detail below. The current embodiment of second gear reduction assembly **232** includes four gears. However, other embodiments could use any other number of gears. Likewise, the number of gears comprising first gear reduction assembly **230** may vary in different embodiments. Additionally, in different embodiments, the type of gears used in first gear reduction assembly **230** and/or second gear assembly **232** could vary. In some cases, spur gears may be used. Other examples of gears that may be used include, but are not limited to: helical gears, external gears, internal gears, bevel gears, crown gears, worm gears, non-circular gears, rack and pinion gears, epicyclic gears, planetary gears, harmonic drive gears, cage gears, magnetic gears as well as any other kinds of gears and/or any combinations of various kinds of gears. The number, type and arrangement of gears for gear reduction system **228** may be selected to achieve the desired tradeoff between size, torque and speed of the motorized tensioning system **160**.

In some embodiments, motorized tensioning system **160** can include provisions for winding and unwinding portions of a lace. In some embodiments, motorized tensioning system **160** can include spool **240**. In some cases, spool **240** may further comprise a first receiving portion **242** and a second receiving portion **244** for receiving a lace and a portion of a spring, respectively. Moreover, in some cases, first receiving portion **242** may comprise a first lace winding region **246** and a second lace winding region **248**, which in some cases can be used to separately wind two ends of a lace. Since torque output goes down as the lace builds up in diameter, using separate winding regions for each lace end may help decrease the diameter of wound lace on spool **240** and thereby minimize torque output reduction. In some cases, first lace winding region **246** and second lace winding region **248** may be separated by a dividing portion **249**, which may include a lace receiving channel **247** for permanently retaining a portion of the lace on spool **240**. In other cases, however, first receiving portion **242** may comprise a single lace winding region.

Motorized lacing system **160** may include provisions for transferring torque between a final drive gear of second gear reduction assembly **232** and spool **240**. In some embodiments, motorized lacing system **160** may include provisions for transferring torque from second gear reduction assembly **232** (or more generally from gear reduction system **228**) to spool **240** in a manner that allows for incremental tightening, incremental loosening and full loosening of a lace. In one embodiment, motorized lacing system **160** may be configured with a torque transmitting system **250** that facilitates the transmission of torque from fourth gear **237** of second gear reduction assembly **232** to spool **240**.

Torque transmitting system **250** may further comprise various assemblies and components. In some embodiments, torque transmitting system **250** may include a ratcheting assembly **252**, a shaft **254** and a rotation control assembly **256**. As discussed in further detail below, the components of torque transmitting system **250** operate to transmit torque from fourth gear **237** of second gear reduction assembly **232** to spool **240**. More specifically, these components operate in a manner that allows for incremental tightening (spool winding), incremental loosening (spool unwinding) as well as full tension release (during which time substantially no torque is transferred from fourth gear **237** to spool **240**).

In some embodiments, motorized tensioning device **160** may further include a secondary winding assembly **260**. In some embodiments, secondary winding assembly **260** may be configured to apply torque to spool **240** independently of any torque applied by motor **220**. In some cases, for example, secondary winding assembly **260** comprises a spring member **262** and a rotatable spring bearing **264**. Spring member **262** may extends between second receiving portion **244** of spool **240** and spring bearing **264**. In particular, a first end portion **263** of spring member **262** may be associated with spool **240** while a second end portion **265** of spring member **262** may be associated with spring bearing **264**. In operation, spring member **262** may be configured to apply a biasing torque that may tend to rotate spool **240** in the lace winding direction in the absence of other forces or torques (for example when there is slack in the lace). Spring member **262** could be a wind-up spring, a constant force spring, a constant torque spring, a clock spring as well as any other kind of spring.

Some embodiments can also include a fixed bearing **266**, which may be associated with an end of shaft **254**. In some embodiments, fixed bearing **266** may be received within a recess **268** of inner housing portion **216**. In some embodiments, an end of shaft **254** may be disposed within opening **269** of fixed bearing **266**, and may be configured so that shaft **254** can slide through opening **269** to provide some axial movement for shaft **254**.

In some embodiments, motorized tensioning device **160** may include provisions for adjusting the operation of motor **220** according to one or more feedback signals. In some embodiments, for example, motorized tensioning device **160** may include a limit switch assembly **258**. Generally, limit switch assembly **258** may detect current across portions of rotation control assembly **256** and vary the operation of motor **220** according to the detected current. Further details on the operation of limit switch assembly **258** are discussed in detail below.

For purposes of reference, the following detailed description uses the terms "first rotational direction" and "second rotational direction" in describing the rotational directions of one or more components about an axis. For purposes of convenience, the first rotational direction and the second rotational direction refer to rotational directions about a longitudinal axis **284** (see FIG. **12**) of shaft **254** and are generally opposite rotational directions. The first rotational direction may refer to the clockwise rotation of a component about longitudinal axis **284**, when viewing the component from the vantage point of first end portion **620** of shaft **254**. First end portion **620** of shaft **254** may be the end portion associated with fourth gear **237**. The second rotational direction may be then be characterized by the counterclockwise rotation of a component about longitudinal axis **284**, when viewing the component from the same vantage point.

A brief overview of the operation of motorized tensioning device **160** is described here. A detailed description of the operation is given below. In the incremental tighten mode motor **220** may begin operating in order to rotate crankshaft **222**. Crankshaft **222** may turn an input gear of first gear reduction assembly **230**, such that the output gear of first gear reduction assembly **230** drives first gear **234** of second gear reduction assembly **232**. The intermediate second gear **235** and third gear **236** both rotate, which drives fourth gear **237** in the first rotational direction. As fourth gear **237** rotates, fourth gear **237** may engage and drive torque transmitting system **250** such that spool **240** may eventually begin to rotate in the first rotational direction. This causes lace **152** to wind onto first receiving portion **242** of spool **240**.

In the incremental loosen mode, motor **220** may operate to rotate crankshaft **222**. In the loosening mode, motor **220** and crankshaft **222** turn in an opposite direction of the direction associated with tightening. The gear reduction system **228** is then driven such that fourth gear **237** of second gear reduction assembly **232** rotates in the second rotational direction. In contrast to the incremental tighten mode, in the incremental loosen mode fourth gear **237** does not directly drive portions of torque transmitting system **250** and spool **240**. Instead, the motion of fourth gear **237** in the second rotational direction causes torque transmitting system **250** to momentarily release spool **240**, allowing spool **240** to unwind by a predetermined amount after which torque transmitting system **250** reengages spool **240** and prevents further unwinding. This sequence of releasing and catching spool **240** occurs over and over as long as fourth gear **237** rotates in the second rotational direction. Further details of the method by which this incremental loosening is achieved is described in detail below.

Finally, in the open or fully loosen mode, torque transmitting system **250** operates so that substantially no torque is transmitted to spool **240** from any components of torque transmitting system **250**. During this mode, spool **240** may rotate more easily in the unwinding direction about shaft **254** (for example, as a wearer manually loosens lace **152** to take off article **100**). As slack forms along the lace, secondary winding assembly **260** may apply a small amount of torque to second receiving portion **244** of spool **240**, which acts to wind up slack in lace **152**.

Torque Transmitting System

FIGS. **10-14** illustrate various schematic views of the components comprising torque transmitting system **250**. For purposes of clarity, these components are shown in isolation from other parts of motorized tightening device **160**. Additionally, some components are not shown or may be shown in phantom in some views to reveal interior components.

Referring first to FIGS. **10** and **11**, ratcheting assembly **252** may comprise several components including fourth gear **237**, pawl member **600** and ratchet housing **602** (ratchet housing **602** is not shown in FIG. **11** to better show the relative positions of fourth gear **237**, pawl member **600** and spool **240**). Fourth gear **237** may include an extended boss portion **604**. In some embodiments, the extended boss portion **604** further includes a frictional face **606** that contacts pawl member **600**. Fourth gear **237** may also include an internally threaded cav-

ity **608** that may engage threading on shaft **254**. For purposes of convenience, fourth gear **237** is characterized as part of both ratcheting assembly **252** and second gear reduction assembly **232** as fourth gear **237** acts as an element that confronts and directly drives pawl member **600** and also as a final driving gear of second gear reduction assembly **232**. In particular, it is to be understood that characterizing fourth gear **237** as part of one assembly does not preclude it from being associated with a different assembly.

In some embodiments, pawl member **600** is configured to interface with ratchet housing **602**. In particular, teeth **610**, which extend from pawl arms **611**, may engage with corresponding teeth **612** on ratchet housing **602**. In some cases the geometry of pawl arms **611** and teeth **610** provide an arrangement where pawl member **600** can rotate within ratchet housing **602** in a first rotational direction, but pawl member **600** is prevented from rotating within ratchet housing **602** in a second rotational direction that is opposite of the first rotational direction.

In some embodiments, pawl member **600** includes a boss engaging surface **614** that confronts and can engage frictional face **606** of fourth gear **237**. When frictional face **606** of fourth gear **237** is brought into contact with boss engaging surface **614** of pawl member **600**, fourth gear **237** may drive pawl member **600**. Moreover, the one-way ratchet design of ratcheting assembly **252** ensures that fourth gear **237** may only drive pawl member **600** in a first rotational direction.

Pawl member **600** may include a spool engaging surface **616** (see also FIG. **16**) which confronts a first end **670** of spool **240**. When spool engaging surface **616** is pressed against spool **240** with enough frictional force, pawl member **600** may be used to drive spool **240** in the first rotational direction. Thus, in the configuration shown in FIG. **11**, with fourth gear **237**, pawl member **600** and spool **240** all clamped together under sufficient frictional force, fourth gear **237** may act to drive pawl member **600** and thus spool **240**.

Ratcheting assembly **252** is only intended to be exemplary of a one-way torque transmitting mechanism that may be used to transmit torque to a spool. Other embodiments are not limited to ratchet-like mechanisms and could include other one-way mechanisms. Examples of other one-way mechanisms that could be used include, but are not limited to: roller bearings, sprag clutches, ratcheting wheel and pawl as well as other mechanisms.

FIGS. **12-14** illustrate various views of additional components of torque transmitting system **250**, including shaft **254** and rotation control assembly **256**. In particular, FIG. **12** illustrates an isolated exploded view of shaft **254** and rotation control assembly **256**, while FIGS. **13-14** illustrate assembled views of some portions of these components from various perspectives.

Shaft **254** may comprise a first end portion **620**. In some embodiments, first end portion **620** may include threading **624**. In some cases, threading **624** may engage internally threaded cavity **608** (see FIG. **10**) of fourth gear **237**, which may facilitate the relative axial movement of fourth gear **237** along shaft **254**. Shaft **254** may also include a second end portion **622** that engages opening **269** of fixed bearing **266**. In some embodiments, an intermediate portion **626** of shaft **254** may be disposed between first end portion **620** and second end portion **622**.

Various portions of shaft **254** are configured to receive components of torque transmitting system **250** and spool **240**. First end portion **620** and second end portion **622** may be associated with ratcheting assembly **252** and rotation control assembly **256**, respectively. Intermediate portion **626** may be inserted within a central cavity **690** of spool **240** (see FIG. **15**), such that spool **240** may rotate about intermediate portion **262**.

In some embodiments, intermediate portion **626** of shaft **254** further includes a flange portion **628** that extends radially outwards from shaft **254**. Flange portion **628** may include a spool engaging surface **630** that contacts spool **240**. An opposing surface of flange portion **628** (not shown) may confront rotation control assembly **256**. In some embodiments, flange portion **628** may include one or more slots **632**.

In some embodiments, rotation control assembly **256** may include an engagement plate **640** and a compression spring **642**. In some embodiments, engagement plate **640** further includes pins **644** that extend towards engagement plate **640** and spool **240**. In some embodiments, pins **644** may be inserted through slots **632** of flange portion **628**. Moreover, in some cases, pins **644** may be inserted into alignment holes **650** of spool **240** (see FIG. **15**), which prevents shaft **254** and spool **240** from rotating independently of one another.

As seen in FIGS. **12-14**, the components of rotation control assembly **256** are disposed along second end portion **622** of shaft **254**. In some embodiments, compression spring **642** may be disposed between engagement plate **640** and fixed bearing **266** so that compression spring **642** may act to bias engagement plate **640** in an axial direction towards flange portion **628** and spool **240**.

In other embodiments, alternate methods could be used for releasably coupling a shaft and spool. Examples include other kinds of physical interlocking features or including friction increasing features. As one example, axial compliant friction coupling could be achieved using a wave washer or Belleville washer.

FIG. **15** illustrates an isometric view of an embodiment spool **240** in isolation. As previously described, spool **240** includes provisions for receiving pins **644** of engagement plate **640**. In this case, four alignment holes **650** are approximately evenly spaced about a second end face **673**. Additionally, this particular view of spool **240** clearly illustrates a slot **675** that may be used for retaining an end of spring member **262**.

Referring now to FIG. **16**, the components of torque transmitting system **250** are shown in their assembled configuration along shaft **254**. For purposes of reference, spool **240** is shown in phantom on shaft **254**. In addition, a cross-sectional portion of inner housing portion **216** is shown for reference. As also seen in FIG. **8**, when installed within inner housing portion **216**, some components of torque transfer system **250** are constrained from any axial movement. For example, spool **240** and ratchet housing **602** are constrained from moving in an axial direction (or along a longitudinal direction of shaft **254**). In contrast, fourth gear **237**, which is threaded along first end portion **620** of shaft **254**, can rotate about shaft **254** and translate axially (because of the threaded engagement) along shaft **254**. In some embodiments, a wall portion **652** of inner housing portion **216** limits the axial motion of fourth gear **237** in a direction away from ratcheting assembly **252**.

The arrangement shown here for torque transmitting system **250** also allows for both rotation and axial translation of shaft **254**. In particular, second end portion **622** of shaft **254** may slide through fixed bearing **266**, while first end portion **620** of shaft **254** is disposed in a channel **660** of inner housing portion **216** (see FIG. **8**) that also allows for some axial motion of shaft **254**. In some embodiments, the amount of axial translation may be limited by features including contact between flange portion **628** and spool **240**, as well as possibly other features.

FIGS. **17** through **26** illustrate schematic views of torque transmitting system **250** and spool **240** for purposes of illustrating the operation of torque transmitting system **250** during incremental tightening, incremental loosening and full loosening. Referring first to FIG. **17**, torque transmitting system **250** is in a configuration where the lace is fully loosened. More specifically, this configuration is one in which no torque is transmitted to spool **240** from torque transmitting system **250**. In this configuration, fourth gear **237** may be spaced away from pawl member **600** (disposed within ratchet housing **602**) so that no torque is transmitted from fourth gear **237** to pawl member **600**. Furthermore, without fourth gear **237** to provide any clamping pressure against pawl member **600** and spool **240**, spool **240** may rotate without any substantial resistance at first end portion **670** from pawl member **600**. Furthermore, in this configuration engagement plate **640** and flange portion **628** are spaced apart from second end **672** of spool **640**, so that spool **240** also does not undergo any resistance to rotation at second end **672**. Although features of inner housing portion **612** prevent any axial motion of spool **240**, in this configuration spool **240** may rotate in a first rotational direction or a second rotational direction. As previously described, spool **240** may be biased to rotate in a first rotational direction (i.e., lace winding direction) by secondary winding assembly **260** (not shown), which applies a biasing torque to spool at second receiving portion **244**. However, this biasing force may be just large enough to pull in slack and can be overcome relatively easily by a wearer pulling on the laces to unwind them from spool **240**. Thus, spool **240** may rotate relatively freely in this configuration, though spool **240** will be biased to wind in slack in the absence of tension applied by the lace to spool **240**.

As also shown in FIG. **17**, in this fully loosened configuration the contacts **259** of limit switch assembly **258** are pressed against engagement plate **640**. This contact with engagement plate **640** provides continuity for the switch, so that current may flow between contacts **259**.

FIG. **18** shows the operation of torque transmitting system **250** as motor **220** (not shown) begins to rotate. Initially, motor **220** drives gear reduction system **228**, so that fourth gear **237** is rotated in the first rotational direction (represented schematically by arrow **700**). As fourth gear **237** rotates in the first rotational direction, fourth gear **237** translates axially (indicated by arrow **702**) towards pawl member **600** because of the threaded interface between fourth gear **237** and shaft **254**. Fourth gear **237** continues to rotate and translate axially until frictional face **606** of boss portion **604** contacts and presses against boss engaging surface **614** of pawl member **600**. At this point, the preload from compression spring **642** may provide some drag on engagement plate **640** and flange portion **628** (which are coupled) to keep shaft **254** from rotating while fourth gear **237** translates axially along shaft **254**. Without this drag, or another source of friction or drag, shaft **254** may be inclined to turn with fourth gear **237** so that fourth gear **237** would not translate axially.

FIG. **19** shows the operation of torque transmitting system **250** in a configuration where spool **240** may begin to wind in lace (i.e., torque transmitting system **250** is in the incremental tighten mode). In this case, motor **220** continues to drive fourth gear **237** in the first rotational direction (indicated schematically as arrow **700**), though contact with pawl member **600** prevents any further axial translation of fourth gear **237** along shaft **254**. Therefore, as fourth gear **237** continues to turn, shaft **254** is translated axially (indicated schematically as arrow **706**) so that first end portion **620** translates further from spool **240**. As shaft **254** translates axially, flange portion **628** compresses against second end **672** of spool **240**, allowing pins **644** to engage alignment holes (see FIG. **15**) of spool **254**. This locks shaft **254** and spool **240** together and prevents relative rotation of the two components. The contact between flange portion **628** and spool **240** prevents any further axial translation of shaft **254**. At this point, with ratcheting assembly **252** clamped against first end portion **670** of spool **240**, further driving of fourth gear **237** acts to rotate spool **240** in the first rotational direction (indicated schematically by arrow **708**). As long as motor **240** continues to drive fourth gear **237**, lace may be wound onto spool **240**.

It can also be seen in FIG. **19** that as flange **628** moves towards spool **240** and engagement plate **640** follows under the force of compression spring **642**, limit switch assembly **258** is separated from engagement plate **640**. This breaks the continuity of current between contacts **259**.

FIGS. **20** and **21** illustrate close up schematic views of some components. For purposes of illustration, a schematic lace **720** is shown with spool **240**. Referring to FIGS. **20** and **21**, ratcheting assembly **252** ensures that torque can only be transmitted from fourth gear **237** to pawl member **600** and spool **240**, and not vice versa. In particular, the one-way operation of ratcheting assembly **252** prevents torque generated by spool **240** from turning pawl member **600**, fourth gear **237** and ultimately motor **220**. In other words, as previously described, ratcheting assembly **252** functions as a load-holding mechanism that prevents spool **240** from unintentionally rotating in the second rotational direction (i.e., the unwinding direction). This arrangement may help prevent spool **240** from back winding motor **220** in situations where motor **220** stops or the torque applied to spool **240** by the lace exceeds to torque applied to the spool by fourth gear **237**.

FIGS. **22-25** show the operation of torque transmitting system **250** in an incremental loosen mode. In some embodiments, incremental loosening may occur in several stages. During a first stage, shown in FIGS. **22** and **23**, motor **220** is operated to drive fourth gear **237** in the second rotational direction (indicated schematically as arrow **730**). This causes fourth gear **237** to translate axially away from pawl member **600** and spool **240** in a direction indicated schematically by arrow **732**. As fourth gear **237** translates away from pawl member **600**, the clamping force between fourth gear **237**, pawl member **600** and first end **670** of spool **240** is released. During a second stage, shown in FIG. **24**, tension in the lace then causes spool **240** to rotate in the second rotational direction (indicated schematically by arrow **734**). Because spool **240** and shaft **254** are physically locked together at this stage, shaft **254** rotates along with spool **240** in the second rotational direction (indicated schematically by arrow **736**). As shaft **254** rotates the threaded engagement between shaft **254** and fourth gear **237** (as well as the resistance to the rotation of fourth gear **237** provided by gear reduction system **228** and motor **220**) causes fourth gear **237** to translate axially towards pawl member **600**. In the last stage, shown in FIG. **25**, fourth gear **237**, pawl member **600** and spool **240** are clamped together, which prevents spool **240** from further rotation in the second rotational direction. These three stages may be repeated in succession to incrementally unwind lace from spool **240**.

FIG. **26** shows the operation of torque transmitting system **250** in a fully loosen mode (or full release mode). Referring to FIG. **26**, motor **220** may drive fourth gear **237** to rotate in the second rotational direction (indicated schematically by arrow **740**) until the lace tension is low enough that spool **240** no longer unwinds. In some embodiments, fourth gear **237** may continue to rotate until fourth gear **237** encounters a hard stop provided by wall portion **652** of inner housing portion **216**. With fourth gear **237** unable to translate further, continued

driving of fourth gear **237** by motor **220** results in shaft **254** translating axially in the direction indicated schematically by arrow **742** until engagement plate **628** is no longer locked with spool **240** (i.e., until pins **644** disengaged from alignment holes **650** of spool **240**). At this point, engagement plate **640** touches contacts **259** of limit switch assembly **258**, thereby completing the limit switch continuity, which further causes motor **220** to stop. This leaves spool **240** in a fully loosened state and able to rotate relatively freely, though with some biasing in the first rotational direction provided by secondary winding assembly **260**.

Secondary Winding Assembly

A secondary winding assembly may be configured to operate substantially independently of a torque transmitting system. This may allow the winding assembly to draw in slack during various stages of operation of the torque transmitting system. In particular, the secondary winding assembly may be configured to draw in slack in a tensioning member (e.g., lace), which could occur during tightening, loosening and fully loosening of the tensioning member.

FIGS. **27** through **29** illustrate schematic isometric views of some portions of motorized tightening device **160**. More specifically, FIGS. **27** through **29** are intended to illustrate the general operation of secondary winding assembly **260** during different operating modes of the system. FIG. **27** illustrates a configuration of motor tightening device **160** operating in a tightening mode. In this mode, fourth gear **237**, in cooperation with torque transmitting system **250**, drives spool **240** in a first rotational direction and thereby winds lace **800** around spool **240**. In this mode, spring member **262** may be wound from spool **240** to spring bearing **264** as spool **240** is driven by the motor.

Referring next to FIG. **28**, when motorized tightening device **160** operates in a fully loosened mode, the tension of lace **800** rotates spool **240** in the second winding direction and unwinds lace **800** from spool **240**. As spool **240** winds in the second rotational direction, spring member **262** may unwind from spring bearing **264** and onto second receiving portion **244** of spool **240**. This allows spring member **262** to return to a default configuration, in which secondary winding assembly **260** tends to bias spool **240** in the winding direction to draw in slack.

Referring next to FIG. **29**, motorized tightening device **160** is operating in a mode where no torque is being supplied to spool **240** by a motor. In addition, slack has developed in lace **800** so that lace **800** is not applying much torque to spool **240** either. In this situation, secondary winding assembly **260** provides a biasing force to wind spool **240** in the first rotational direction, as spring member **262** unwinds from second receiving portion **244** of spool **240** and onto spring bearing **264**.

Secondary winding assembly **260** may improve usability of tensioning system **150**, by ensuring that slack is rapidly wound up when motor **220** is disengaged. This is desirable so a user can quickly put the article on or take the article off without having to wait for the motor to wind in slack. In the embodiment shown, this rapid slack winding is accomplished using constant force spring that is stored on a freewheeling spool and rewound onto one end of the lace spool. However, in other embodiments, a variety of different elements or systems could be used for this rapid slack winding. For example, in another embodiment a second small motor with either no reduction or light gear reduction could be used for slack winding. In still other embodiments, other spring elements could be used. For example, in another embodiment, an elastomeric torsion spring could be used. In still another embodiment, a geared clock spring could be used. Moreover, in other embodiments, a spring member could be wound onto other components of a tightening system. For example, in the alternative embodiment shown in FIG. **30**, spring member **820** is configured to wind around spool **240** at one end, and around motor **220** at another. This alternative arrangement may provide a slightly more compact configuration for a motorized tightening system. In addition to improving the speed of fully winding and unwinding the lace, battery life may be greatly improved over systems that utilize a motor to completely wind and unwind a lace.

Placement

The location of a motorized tensioning device can vary from one embodiment to another. The illustrated embodiments show a motorized tensioning device disposed on the heel of an upper. However, other embodiments may incorporate a motorized tensioning device in any other location of an article of footwear, including the forefoot and midfoot portions of an upper. In still other embodiments, a motorized tensioning device could be disposed in a sole structure of an article. The location of a motorized tensioning device may be selected according to various factors including, but not limited to: size constraints, manufacturing constraints, aesthetic preferences, optimal lacing placement, ease of removability as well as possibly other factors.

In embodiments where motorized tensioning device **160** is disposed externally on upper **102**, a wearer may access components by removing a portion of housing unit **212** (see FIG. **1**). For example, in some cases spool **240** may be replaceable in the event of a broken lace.

Some embodiments may include provisions for incorporating a motorized tensioning device into removable components of an article. In one embodiment, a motorized tensioning device may be incorporated into an external heel counter. In some cases, an external heel counter may function as a harness for mounting a motorized tensioning device to an article. In such embodiments, the external heel counter may be specially adapted to receive a motorized tensioning device. An example of a heel counter configured for use with a lace tensioning device is disclosed in Gerber, U.S. Patent Application Publication Number 2013/0312293, now U.S. patent application Ser. No. 13/481,132, filed May 25, 2012 and titled "Article of Footwear with Protective Member for a Control Device", the entirety of which is hereby incorporated by reference.

Battery and Control Unit

Embodiments may include a battery and/or control unit configured to power and control motorized tensioning device **160**. FIG. **31** illustrates a schematic view of an embodiment of article **100** including motorized tensioning device **160**, battery **300** and control unit **302**. In the embodiment of FIG. **31**, motorized tensioning device **160**, battery **300** and control unit **302** are all disposed in an external heel counter **304**, which may function to receive and protect these components. In other embodiments, however, any of these components could be disposed in any other portions of an article, including the upper and/or sole structure. In some cases, some components could be disposed in one portion of an article and other components could be disposed in another, different, portion. In another embodiment motorized tensioning device **160** could be disposed at the heel of an upper, while battery **300** and/or control unit **302** could be disposed with a sole structure of article **100**. For example, in one embodiment the battery and controller unit may be disposed under midfoot portion **12** of article **100** with a cable connection (or a simple electrical contact connection) to motorized tensioning device **160**, which may be disposed in heel portion **14**. In still other embodiments, a battery and a control unit could be integrated

into a motorized tensioning device. For example, in some embodiments, both a battery and a control unit could be disposed within housing unit **212** (see FIG. **1**) of motorized tensioning device **160**.

Battery **300** is only intended as a schematic representative of one or more types of battery technologies that could be used to power motorized tightening device **160**. One possibly battery technology that could be used is a lithium polymer battery. The battery (or batteries) could be rechargeable or replaceable units packaged as flat, cylindrical, or coin shaped. In addition, batteries could be single cell or cells in series or parallel.

Rechargeable batteries could be recharged in place or removed from an article for recharging. In some embodiments, charging circuitry could be built in and on board. In other embodiments, charging circuitry could be located in a remote charger. In another embodiment, inductive charging could be used for charging one or more batteries. For example, a charging antenna could be disposed in a sole structure of an article and the article could then be placed on a charging mat to recharge the batteries.

Additional provisions could be incorporated to maximize battery power and/or otherwise improve use. For example, it is also contemplated that batteries could be used in combination with super caps to handle peak current requirements. In other embodiments, energy harvesting techniques could be incorporated which utilize the weight of the runner and each step to generate power for charging a battery.

Control unit **302** is only intended as a schematic representation of one or more control technologies that could be used with motor tensioning device **160**. For example, there are various approaches to motor control that may be employed to allow speed and direction control. For some embodiments, a microcontroller unit may be used. The microcontroller may use internal interrupt generated timing pulses to create pulse-width modulation (PWM) output. This PWM output is fed to an H-bridge which allows high current PWM pulses to drive the motor both clockwise and counterclockwise with speed control. However, any other methods of motor control known in the art could also be used.

Apparel

A tensioning system as described above is not limited to articles of footwear and could be used with apparel, for example. As one particular example, FIGS. **32-36** illustrate an embodiment where a tensioning system **320** is used with an article of apparel **322**. In this case, article of apparel **322** may be a layer of clothing that incorporates shoulder pads **324**. For purposes of clarity, the description below discusses the use of tensioning system **320** for adjusting a first shoulder pad **326**, however, it will be understood that a substantially similar tensioning system could also be used to adjust a second shoulder pad **328** in a similar manner.

As seen in FIG. **32**, the embodiment discussed here may be used for padding worn by a user **330** playing American football, where shoulder pads are common. However, other embodiments could use this adjustable shoulder pad configuration with any other kinds of clothing configured to be worn by players in any other sports, including, for example, hockey, lacrosse, as well as any other sports or activities requiring shoulder pads. Moreover, it should be understood that the principles discussed here can be used for adjusting any kinds of padding including, but not limited to: elbow pads, knee pads, shin pads, padding associated with the hands and arms, padding associated with the feet and legs, padding associated with the torso, padding associated with the head as well as any other kind of padding known in the art.

Referring now to FIGS. **33** and **34**, first shoulder pad **326**, referred to hereafter simply as pad **326**, may comprise a plurality of padding elements **340**. In one embodiment, the geometry of these padding elements **340** is approximately hexagonal. Moreover, the plurality of padding elements **340** may be spaced apart from one another in a default configuration of pad **326**.

In order to control the spacing between plurality of padding elements **340**, some embodiments can utilize tensioning system **320** to apply an inwardly tensioning force that squeezes plurality of padding elements **340** closer together. In some embodiments, tensioning system **320** may include a motorized tensioning device **342** and a cable **344**. In some embodiments, motorized tensioning device **342** is mounted onto article of apparel **322** at a location adjacent to pad **326**. Cable **344** extends from motorized tensioning device **342** and wraps around a perimeter of pad **326**, thereby surrounding the outer most elements of plurality of padding elements **340**. In some cases, cable **344** may be placed through one or more cable guides or lace guides, however in other cases cable **344** may wrap around the perimeter of pad **326** without the use of any guides.

In the default configuration cable **344** is generally loose and applies no tension to pad **326**. This is the configuration shown, for example, in FIG. **33**. In order to compress or tighten pad **326**, user **330** may press the incremental tightening button **346** on remote device **348**, which sends tensioning commands to motorized tensioning device **342** (or to a separate control unit of motorized tensioning device **342**). As cable **344** is tightened (see FIGS. **34** and **36**), cable **344** applies an inward tensioning force on the outer most elements of plurality of padding elements **340**, which may squeeze plurality of padding elements **340**. This decreases the spacing between adjacent padding elements **340** and increases the overall density of pad **326**, which may increase the overall stiffness of pad **326** as compared to the stiffness of pad **326** in the default configuration. In other words, motorized tensioning device **342** may be used to adjust the stiffness of pad **326** from a first stiffness associated with a non-tensioned state of cable **344** to a second stiffness associated with a tensioned state of cable **344**, where the second stiffness is substantially greater than the first stiffness. This feature may be used to adjust padding stiffness according to playing conditions (dry, wet, turf, grass, etc.) as well as activity type (practice vs. game) or any other factors.

A tensioning system including a motorized tensioning device may be used with any other kinds of apparel. Some examples of other apparel are shown in FIG. **37**, which illustrates schematic views of a backpack **350** and a hat **354**, and a corresponding first tensioning system **356** and second tensioning system **358**, respectively. For example, first tensioning system **356** may apply tension to a cable **372**, which adjusts the tightness of straps **374** of backpack **350**. Likewise, second tensioning system **358** may apply tension to a cable or band **380** that circumscribes the periphery of hat **354** and therefore can be used to adjust the size of opening **382** of hat **354**.

Further examples of articles that can be used with tensioning systems are disclosed in Soderberg et al., U.S. Patent Application Publication Number 2010/0139057, now U.S. patent application Ser. No. 12/623,362, filed Nov. 20, 2009 and titled "Reel Based Lacing System" (the "'362 application"), the entirety of which is hereby incorporated by reference. Still further examples of articles that can be used with tensioning systems are disclosed in Soderberg et al., U.S. Patent Application Publication Number 2009/0184189, now U.S. patent application Ser. No. 12/355,675, filed Jan. 16,

2009 and titled "Closure System" (the "Closure system application"), the entirety of which is hereby incorporated by reference. It is contemplated that in some embodiments a motorized tensioning device could be incorporated into the articles described in the '362 application as well as articles described in the Closure system application, including a helmet, a hat, a glove, a backpack and/or hydration carrier, a belt, bindings for boots, a wrist guard and a sandal.

In still other embodiments, a tensioning system including a motorized tensioning device can be used with any other kinds of apparel and/or sports equipment including, but not limited to gloves, shirts, pants, socks, scarves, jackets, as well as other articles. Other examples of articles include, but are not limited to: shin guards, knee pads, elbow pads, shoulder pads, as well as any other type of protective equipment. Additionally, in some embodiments, the flexible manufacturing system could be used with bags, duffel bags, purses, backpacks, luggage, various kinds of sportswear and/or sporting equipment.

Alternative Controls

In different embodiments, control of a motorized lacing device can be accomplished using various methods and devices. Referring now to FIG. **38**, some embodiments may utilize various kinds of remote devices, including an RF based control bracelet **390**. Control bracelet **390** may incorporate one or more buttons for sending commands to a motorized tensioning device. In some cases, control bracelet **390** may include buttons for initiating incremental tightening and incremental loosening commands. In still other cases, additional buttons can be included for initiating any other commands including the open command (or fully loosen command), store tension command and return to stored tension command. Still other cases could incorporate any other buttons for issuing any other kinds of commands.

In some other embodiments, buttons for tightening, loosening and/or performing other functions can be located directly on an article. As an example, some embodiments could incorporate one or more buttons located on or adjacent to the housing of a motorized tensioning device. In still other embodiments, a motorized tightening device may be controlled using voice commands. These commands could be transmitted through a remote device, or to a device capable of receiving voice commands that is integrated into the article and in communication with the motorized tensioning device.

Sensors

Embodiments can incorporate a variety of sensors for providing information to a control unit of a motorized tensioning system. As described above, in some embodiments an H-bridge mechanism is used to measure current. The measured current is provided as an input to control unit **302** (see FIG. **31**). In some cases, a predetermined current may be known to correspond to a certain lace tension. By checking the measured current against the predetermined current, a motorized tensioning system may adjust the tension of a lace until the predetermined current is measured, which indicates the desired lace tension has been achieved.

With current as a feedback, a variety of digital control strategies can be used. For instance, proportional control only could be used. Alternatively, PI control could be used or full PID. In cases some cases, simple averaging could be used or other filtering techniques including fuzzy logic and band-pass to reduce noise.

Still other embodiments can include additional types of sensors. In some cases, pressure sensors could be used under the insoles of an article to indicate when the user is standing. A motorized tensioning system can be programmed to automatically loosen the tension of the lace when the user moves from the standing position to a sitting position. Such a configuration may be useful for older adults that may require low tension when sitting to promote blood circulation but high tension for safety when standing.

Still other embodiments could include additional tension sensing elements. In one embodiment, three point bend indicators could be used in the lace to more accurately monitor the state of the tensioning system, including the lace. In other embodiments, various devices to measure deflection such as capacitive or inductive devices could be used. In some other embodiments, strain gauges could be used to measure tension induced strain in one or more components of a tensioning system.

In some embodiments, sensors such as gyroscopes and accelerometers could be incorporated into a tensioning system. In some embodiments, an accelerometer and/or gyroscope could be used to detect sudden moment and/or position information that may be used as feedback for adjusting lace tension. These sensors could also be implemented to control periods of sleep/awake to extend battery life. In some cases, for example, information from these sensors could be used to reduce tension in a system when the user is inactive, and increase tension during periods of greater activity.

Some embodiments may use memory (for example onboard memory associated with a control unit) to store sensed data over time. This data may be stored for later upload and analysis. For example, one embodiment of an article of footwear may sense and store tension information over time that can be later evaluated to look at trends in tightening.

It is also contemplated that some embodiments could incorporate pressure sensors to detect high pressure regions that may develop during tightening. In some cases, the tension of a lace could be automatically reduced to avoid such high pressure regions. Additionally, in some cases, a system could prompt a user to alter them to these high pressure regions and suggest ways of avoiding them (by altering use or fit of the article).

It is contemplated that in some embodiments a user could be provided with feedback through motor pulsing, which generates haptic feedback for the user in the form of vibrations/sounds. Such provisions could facilitate operation of a tensioning system directly, or provide haptic feedback for other systems in communication with a motorized tensioning device.

Control Methods

Various methods of automatically operating a motorized tensioning device in response to various inputs can be used. For example, after initially tightening a shoe, it is common for the lace tension to quickly decline in the first few minutes of use. Some embodiments of a tensioning system may include provisions for readjusting lace tension to the initial tension set by the user. In some embodiments, a control unit may be configured to monitor tension in those first minutes to then readjust tension to match original tension.

FIG. **39** is a schematic view of an exemplary process for automatically readjusting lace tension to maintain the user desired tension over time. In some embodiments, some of the following steps could be accomplished by a control unit **302** (see FIG. **31**) associated with motorized tensioning device **160**. In other embodiments, some of the following steps could be accomplished by other components of a tensioning system. It will be understood that in other embodiments one or more of the following steps may be optional.

In step **502**, control unit **302** may determine if a user has finished tightening an article. In some cases, control unit **302** may determine that a user has finished tightening a lace if no control commands (e.g., an incremental tighten command)

have been received after a predetermined period of time. If control unit **302** determines that the user has finished tightening the article, control unit **302** proceeds to step **504**. Otherwise, control unit **302** may wait until it has been determined that the user has finished tightening the article.

In step **504**, control unit **302** may monitor tension of the tensioning system (e.g., tension of a lace) for a predetermined interval to determine an initial tension. Methods for monitoring tension, including current sensors and other sensors have been previously discussed above. In some cases, control unit **302** may set the average measured tension over the predetermined interval as the initial tension.

Next, in step **506**, control unit **302** may determine if the tension of the tensioning system has decreased. If not, control unit **302** may wait and then reevaluate if the tension has decreased. Once it has been determined that the tension has decreased, control unit **302** may proceed to step **508**. In step **508**, control unit **302** may automatically increase the tension of the tensioning system until the initial tension has been achieved. In some embodiments, after step **508**, control unit may wait and again automatically evaluate the tension at step **506**. In some embodiments, control unit **302** may be additionally configured to automatically detect overtension and in response automatically decrease the tension of the tensioning system until the initial tension has been achieved. In some embodiments, control unit **302** may be configured to perform cyclic changes in tension, such as to enhance blood circulation.

In some embodiments, instead of only waiting a determined period of time, as illustrated in FIG. **39** and described above, the reevaluation of step **506** may be triggered by sensor information. In one example, sensor-based triggering may replace the waiting, with sensor information causing reevaluation of tension to occur. In another example, waiting may be performed as illustrated in FIG. **39**, but with sensor information possibly causing the waiting to be terminated and triggering reevaluation of tension. Sensors providing such information to control unit **302** might include, but are not limited to, pressure sensors in shoe insoles to detect standing and/or rate of motion, bend indicators, strain gauges, gyroscopes, and accelerometers. In some embodiments, instead of or in addition to maintaining an initial tension, the sensor information may be used to establish a new target tension. For example, pressure sensors could be used to measure contact pressures of a brace and automatically adjust used to avoid injury due to high pressure. In some embodiments, control unit **302** may be configured to store sensor information obtained over a period of time to identify triggering events. Additionally, control unit **302** may be configured to upload or otherwise provide stored sensor information to a remote device. Uploaded sensor information may be reviewed and analyzed for purposes including, but not limited to, patient compliance for medical device use. Some embodiments may be configured to operate in two or more different modes. For example, some embodiments could operate in a "normal mode" and a "game mode" (or similarly, a "sports mode" or "active mode"). In the normal mode, the electric motor would be powered down after tensioning in order to save battery life. In contrast, when the game mode is selected by a user, the tension of the system may be continuously monitored and adjusted for maximum performance though at the expense of battery life. By enabling a user to change between these two modes, a user can choose to optimize battery life or optimize performance depending on the needs of the situation. In some embodiments, multiple target tensions may be stored and returned to, for either of the "normal mode" or the "game mode," such as configuring a target tension for sport and a substantially different tension for leisure. In some embodiments, control unit **302** may be configured to frequently, but not continuously, monitor and adjust tension, so as to further extend battery life while achieving some of the benefit of a continuously monitored "game mode."

FIG. **40** is a schematic view of an exemplary process for operating a tensioning system in two different modes. In some embodiments, some of the following steps could be accomplished by a control unit **302** (see FIG. **31**) associated with motorized tensioning device **160**. In other embodiments, some of the following steps could be accomplished by other components of a tensioning system. It will be understood that in other embodiments one or more of the following steps may be optional.

In step **510**, control unit **302** may receive the user selected mode. This may be determined by receiving a signal from a remote device, which may prompt a user to select with a "normal mode" or a "game mode". Next, in step **512**, control unit **302** may determine if the user has finished tightening the article. If not, control unit **302** waits until the user has finished tightening the article. When the user has finished tightening the article, control unit **302** proceeds to step **514**. At step **514**, control unit **302** determines which mode has been selected from the information received during step **510**. If the user has selected the normal mode, control unit proceeds to step **516**, where the motor is powered down and the system awaits further instructions from the user (or other systems/sensors) to save battery power. If, however, the user has selected the game mode at step **514**, control unit **302** proceeds to step **518**. During step **518**, control unit **302** may actively monitor the tension of the article and may automatically adjust the tension to achieve maximum performance.

As another example of a process for automatically controlling a tensioning system, GPS feedback from a remote device could be used to determine if a runner is on flat ground, climbing or descending. The system could automatically adjust the tension of the laces in footwear automatically, for example, by increasing tension in the laces during descent.

Although the exemplary methods described above and shown in FIGS. **39** and **40** are directed to footwear, it will be understood that similar methods could be used for automated operation of other kinds of articles including tensioning systems. In particular, these methods could be used with any of the apparel previously discussed.

Alternative Embodiment of Motorized Tightening Device

FIG. **41** shows a schematic view of an alternative embodiment of a motorized tensioning device **900**. For purposes of describing some internal components, FIG. **43** illustrates a cross sectional view of some components of motorized tensioning device **900**. Motorized tensioning device **900** may include some similar provisions as the previous embodiments, for example a motor **902** and a gear reduction system **904** that is driven by motor **902**. Gear reduction system **904** as shown here includes 5 stages of spur gears. Other gear reductions that could be employed include: cycloidal, harmonic, and planetary. In some embodiments, the motor **902** and gear reduction system **904** combination may be sized to maximize the tradeoffs between current requirement, size, torque and speed. In the embodiment shown, the gear reduction is approximately 600:1 with an output RPM of 30 and a peak current of 1.2 amps.

The output of gear reduction system **904** may enter an incrementally releasable load holding mechanism **906**, which is shown in FIG. **42**. This load holding mechanism **906** comprises a ratcheting type mechanism, which helps hold any loads applied to spool **908** without potentially back driving motor **902** and/or gear reduction system **904**. The purpose is

to hold the load without relying on the motor/gearbox to not back drive. Load holding mechanism **906** may hold load on spool **908** even while motor **902** is de-energized. When a small amount of lace tension is desired to be released, motor **902** unwinds and a sweeper element sweeps pawl elements **910** off internal teeth **912** allowing the output to unwind one tooth. This can be repeated as desired to precisely unwind the spool and correspondingly relax lace tension. This is important to allow the user to get to a precise fit. An exemplary load holding mechanism that may be used is disclosed in Soderberg et al., U.S. Patent Application Publication Number 2010/0139057, now U.S. patent application Ser. No. 12/623,362, filed Nov. 20, 2009 and titled "Reel Based Lacing System", the entirety of which is hereby incorporated by reference.

Referring to FIGS. **41** and **43**, the output of load holding mechanism **906** in this embodiment is a male square drive **914**. This drive element could be any number of sides or be an external spline. The male square drive mates with a female element **916** with sufficient clearance and of a material for low friction sliding along shaft **912** (see FIG. **43**). The female element **916** is driven by the male square drive **914**. The opposite end of female element **916** includes a face driving element **920**. In the embodiment shown, this is a large number of triangular teeth which can engage or disengage from matching teeth on one flange of spool **908**. These teeth could be from as few as one to more than eight. To encourage engagement the teeth may be back drafted from 5 to 60 degrees. In some embodiments, the teeth may be angled at approximately 45 degrees.

The center of female element **916** has a thread (not shown) which can engage threaded portion of shaft **912**. When motor **902** is driven in one direction element **916** moves axially as a result of the internal thread and engages the face teeth between itself and corresponding teeth on spool **908**. Shaft **912**, which is normally stationary, has a frictional element **922** to prevent rotation during axial travel and engagement. When engagement is complete and the face teeth are fully engaged, the external thread of shaft **912** will experience torque. Over a certain torque level, motor **902** and gear reduction system **904** will overcome the torsional friction element **922** and shaft **912** will turn. In the embodiment shown, frictional element **922** is an O-ring on shaft **912** that is contained in a housing. The O-ring pressure can be adjusted via a screw which can clamp down on the O-ring. In other embodiments, this torsion friction could be accomplished by a number of means. For example, in another embodiment, torsional friction could be done as a coulomb frictional device such as an adjustable face clutch for instance using steel or brass against nylon or other brake pad materials and adjustable via an axial spring tensioner. In other embodiments, torsional friction could also be done electrically via a particle clutch or hydraulically via a rotary damper. In some embodiments, the number of turns to reach disengagement can be coordinated if desired with the number of turns to go from full lace tension to no tension. That way, incremental release can be done anywhere in the range of lace that is tensioned.

In the embodiment shown, rapid slack wind may be achieved via a constant force spring (not shown) that is stored on a freewheeling spool **930** and rewound onto one end **930** of spool **908**.

In some embodiments, the lace may exit and is tended through radiused eyelets in a housing to prevent lace wear and increase lace fatigue life. In some embodiments, these exits may be located at least ½ of the spool diameter away from the spool to help the lace more or less level wind onto the spool to maximize capacity.

In some embodiments, a user initiated manual release element is also provided should the user every find themselves in tightened shoes with no remaining battery life. Many approaches could be used to manually disengage the spool from the load holding and motor/gearbox mechanism. For instance a tapered blade (not shown) can be inserted between the teeth on spool **908** and element **916** to separate them via a spring element allowing axial movement of spool **908** in the separation direction.

In addition, other example configurations of ratcheting mechanisms for different embodiments of a motorized tensioning device can be understood by studying devices **5300** and **5400** illustrated in FIGS. **53** and **54**.

Alternate Tension and Release Mechanism

FIGS. **44** and **45** illustrate schematic views of an alternative tensioning and release mechanism that could be used with a motorized tightening system. Another view of this mechanism is also shown in FIG. **47**. For purposes of reference, this mechanism is shown in isolation from other components of a tightening device. This mechanism can be used for accomplishing tightening, load holding, incremental release and full release.

In this design, a system of cams and latches are used. Referring to FIGS. **44** and **45**, load holding mechanism **938** includes a final stage output gear **940** of a gear reduction system (not shown) which is connected to a cylindrical plate **942** that has a single driving pawl **944** near its center. In the tightening direction, the motor is continually driven and the pawl **944** drives via detents in an output ring **946** that is attached to the spool. This output ring **946** has internal detents **948** that plate **942** drives and external female teeth **950** that engage an external load holding pawl **954**. When the motor is stopped the external load holding pawl **954** resists the spool torque. It can be seen that plate **942** not only has the internal drive pawl **944** but also has cam elements **945** on its periphery that periodically disengage the external load holding pawl **954**. When stopped and holding load the external pawl is engaged **954**. Then the cylindrical plate **942** begins to back up for an incremental release. At first the output does not release. Then one of cam elements **945** on plate **942** releases outside load holding pawl **954**. When this happens, output ring **946** catches up to pawl **954** and next the load holding pawl **954** engages and the mechanism stops in an incremental load holding position. In this way incremental release is accomplished. For this to operate a limit switch is employed to monitor plate **942** and stop in each incremental release position. In the embodiment shown there are six stop positions or every 60 degrees of rotation. This number can vary based on space requirements and the incremental lace release resolution desired. There could be as few as 1 stop per revolution and as many as 12, for example.

For full release, mechanism **938** must be stopped with both the internal and external pawl released at the same time. There is one more releasing pawl **960** required to accomplish this. In the figure, pawl **960** has three positions. Fully retracted, actuator extended, and releasing cam extended. After tensioning, pawl **960** is fully retracted, as incremental releases are actuated the internal pawl **944** will likely pass this external pawl **960** and set it to the full release position. So when a full release is commanded, the internal pawl **944** will move into a position where both internal and external pawls are lifted and the user can freely extract lace and take off the article while only encountering minimal resistance which is provided by the slack take up mechanism.

Manual Release System

FIG. **46** illustrates an embodiment of an alternative manual release system from the system described above. Referring to

FIG. **46**, article **1000** may be similar to previous embodiments and can include a tensioning system **1002** with a lace **1004** and a motorized tensioning device **1006**. In this embodiment, a portion of lace **1004** is equipped with a manual release mechanism **1010**. In the embodiment shown here, manual release mechanism **1010** includes corresponding fasteners **1012** that can be manually disconnected to relieve lace tension. In some cases, fasteners **1012** comprise a screw together clasp. However, other embodiments could utilized any other fastening provisions including a snap fit connector, a hook and receiver type connector, or any other kinds of fasteners known in the art.

Medical Braces

Embodiments of a tensioning system, including a motorized tightening device may be incorporated into medical braces or other medical protective wear. Examples of different types of braces include, but are not limited to: wrist braces, arm braces, leg braces, knee braces, ankle braces, as well as any other kinds of braces and protective wear. In one embodiment, a motorized tightening device may be incorporated into the lacing system for a medial brace disclosed in Nickel et al., U.S. Patent Application Publication Number 2012/0004587, now U.S. patent application Ser. No. 13/174,533, filed Jun. 30, 2011 and titled "Braces Using Lacing Systems" (the "Braces application"), the entirety of which is hereby incorporated by reference. For example, a motorized tightening device, including various embodiments described here, could be incorporated into a wrist brace or ankle brace, which are described with various manual tightening systems in the Braces application. A motorized tightening device could also be incorporated into the closure system of the orthopedic braces and protective wear disclosed in Hammerslag et al., U.S. Patent Application Publication Number 2008/0066272, now U.S. patent application Ser. No. 11/854,522, filed Sep. 12, 2007 and titled "Closure System for Braces, Protective Wear and Similar Articles" (the "Protective Wear application"), the entirety of which is hereby incorporated by reference. For example, a motorized tightening device could be incorporated into any of the orthopedic devices (such as knee braces and leg braces) that are described with various manual tightening systems in the Protective Wear application. Various exemplary types of braces incorporating tensioning systems with motorized tightening devices are shown in FIGS. **48-52**.

As with footwear and other articles, using a motorized tightening device for a lacing or tensioning system on a brace may provide benefits over manual tightening methods. For example, having a repeatable (measurable) closure may allow a doctor to prescribe a particular tension setting for the brace, allowing the tensioning to act as a repeatable "dosage". Moreover, repeatable closure may improve ease of use allowing a user to put on the brace, press a button and have the brace automatically adjust to the predetermined tension.

It is contemplated that in embodiments including medical braces the "dosing" of the brace tension could be digitally transmitted to a doctor and/or received digitally (at the device) by a doctor. This allows a doctor to efficiently monitor tension, especially as changes may occur due to stretch of the brace, changes in body size, as well as possibly other factors. This also may allow a doctor to tighten the brace (or recommend a tensioning level to the patient) according to a dose level and keep it there over time and as changes occur.

Using a motorized tensioning device may remove dexterity issues that may occur with other tensioning technologies (pulling straps, Velcro, etc. . . .). Such a design could improve the use of braces for physically impaired, or injured individuals who may otherwise have a hard time putting on and adjusting their braces. Using the designs proposed here, a brace could be tightened via a push button or remote interface. An exemplary remote interface **5001** for tightening a knee brace **5002** is shown in FIG. **50**.

In some embodiments, a brace incorporating a motorized tensioning device can be configured to constantly measure internal system tension and then react to maintain a predetermined tension level. This may help reduce over-tensioning of the device. This may also help in automatically adjusting the brace to a limb as it shrinks from swelling reduction and/or atrophy. In some embodiments, the brace could adjust to provide additional support when/if the brace detects unusually high tensions due to a user falling on the injured limb.

Still additional elements can be added to a brace to aid in reactivity. For example, in some embodiments, a member within the brace that is able to shorten and stiffen at either prescribed times, or when additional support is needed. Such a feature could be accomplished using the motorized tensioning technology as well as possibly other provisions.

A motorized tension device used to tension a brace can also facilitate proactive adjustment of the brace. For example, motorized compression can be used for proactively adjusting compression of a bracing product. In one example, a motorized tensioning device may automatically adjust the tension in a brace at timed intervals, which can encourage blood flow and promote healing. As another example, a motorized tensioning device may automatically adjust tension to correspond with the position of a patient's body or activity. For instance, one level of tensioning could be provided for sitting, a second level of tensioning could be provided for standing and a third level of tensioning could be provided for activities such as walking, running or other ambulatory activities. sitting require one level of protection/support/tension

An additional provision that could be used with a brace incorporating a motorized tensioning device for adjusting tensioning in a lace or other tensioning member include a spring based opening. In particular, some embodiments may include a spring between eyestays to keep the brace open when the brace is not in tension. This may make it easier to put the brace on and/or remove the brace. Additionally, this spring based opening may reduce lace tangling issues by proactively keeping lace pulled out of the tensioning device once tension has been released.

Various charging strategies could be employed for a medical brace including inductive charging, plug in charging as well as the use of removable batteries. An example of an inductive charging configuration **5100** for a brace is shown in FIG. **51**.

Examples of user interfaces include a turn dial for tightening or loosening the tension. An exemplary configuration of a back brace **4901** with a motorized tightening device **4902** that uses a turn dial type user control **4903** is shown in FIG. **49**. Another possible interface includes a conductive panel where a user moves their finger up or down to adjust tensioning. FIG. **52** shows one such interface for motorized tightening device **5200**. Still another interface could be a push button interface.

Methods of digitally tracking tensioning data measured by one or more sensors could be used in some embodiments. The average tension of the device could also be tracked, to measure swelling, atrophy, etc. In addition, in some cases, the number of times the brace is put on and taken off can be tracked. Time of use and the level of patient compliance could also be tracked.

Data collection could be facilitated by various technologies including USB devices, data cords and blue tooth communication technologies. Moreover, the data collected can be transmitted through a variety of technologies to either a cen-

tral database for evaluation, and/or directly to a physician to allow them to monitor the progress of a patient. FIG. **48** shows exemplary communication modes between a tightening system **4801** and a computer **4802**, including a Bluetooth connection **4803** and a USB connection **4804**.

While various embodiments of the embodiments have been described, the description is intended to be exemplary, rather than limiting and it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible that are within the scope of the embodiments. Accordingly, the embodiments are not to be restricted except in light of the attached claims and their equivalents. Also, various modifications and changes may be made within the scope of the attached claims.

What is claimed is:

1. An article of footwear, comprising:
- a tensioning member;
- a motorized tensioning device for controlling the tension of the tensioning member;
- at least one sensor for receiving information related to the tension of the tensioning member;
- a control unit, wherein the control unit can receive information from the at least one sensor;
- wherein the control unit operates the motorized tensioning device in a normal operating mode and an active operating mode;
- wherein the control unit powers down the motorized tensioning device after a target tension has been achieved in the normal operating mode;
- wherein during the active operating mode, the control unit continuously monitors the tension of the tensioning member after the target tension has been achieved and adjusts the motorized tensioning device to maintain the target tension; and
- wherein the motorized tensioning device increases the tension in the tensioning member if the tension is less than the target tension and the motorized tensioning device decreases the tension in the tensioning member if the tension is greater than the target tension.

2. The article of footwear according to claim **1**, wherein the normal operating mode is a power saving mode.

3. The article of footwear according to claim **1**, wherein the active operating mode is a sports mode.

4. The article of footwear according to claim **1**, wherein the tension is automatically adjusted in the active operating mode.

5. The article of footwear according to claim **1**, wherein the target tension is determined by a user.

6. The article of footwear according to claim **1**, wherein the at least one sensor is a tension sensor.

7. The article of footwear according to claim **1**, wherein the control unit senses the tension of the tensioning member more frequently during the active operating mode than during the normal operating mode.

8. An article of footwear having an upper and a sole structure, comprising:
- a tensioning member;
- a motorized tensioning device disposed on the upper, the motorized tensioning device controlling the tension of the tensioning member;
- a battery configured to power the motorized tensioning device;
- at least one sensor for receiving information related to the tension of the tensioning member;
- a control unit, wherein the control unit can receive information from the at least one sensor;
- wherein the control unit operates the motorized tensioning device in a normal operating mode and an active operating mode;
- wherein during the normal operating mode, the control unit powers down the motorized tensioning device after a target tension has been achieved; and
- wherein during the active operating mode, the control unit continuously monitors the tension of the tensioning member after the target tension has been achieved and automatically adjusts the motorized tensioning device to maintain the target tension.

9. The article of footwear according to claim **8**, wherein the battery is rechargeable.

10. The article of footwear according to claim **8**, wherein the tensioning member is a lace.

11. The article of footwear according to claim **8**, wherein the tensioning member is guided through a throat opening of the article of footwear.

12. The article of footwear according to claim **11**, wherein the motorized tensioning device adjusts the tension at the throat opening of the article of footwear.

13. The article of footwear according to claim **8**, wherein the motorized tensioning device is disposed on a heel of the upper.

14. The article of footwear according to claim **8**, wherein the control unit increases the tension of the tensioning member until the target tension has been achieved.

15. An article of footwear having an upper and a sole structure, comprising:
- a tensioning member;
- a motorized tensioning device disposed on the upper, the motorized tensioning device controlling the tension of the tensioning member;
- a battery configured to power the motorized tensioning device;
- at least one sensor for receiving information related to the tension of the tensioning member;
- a control unit, wherein the control unit can receive information from the at least one sensor and store the information;
- wherein the control unit operates the motorized tensioning device in a normal operating mode and an active operating mode;
- wherein the control unit powers down the motorized tensioning device after a first target tension has been achieved in the normal operating mode, the first target tension determined by a user; and
- wherein the control unit continuously monitors the tension of the tensioning member after the first target tension has been achieved and adjusts the motorized tensioning device to maintain the first target tension in the active operating mode.

16. The article of footwear according to claim **15**, wherein the motorized tensioning device automatically adjusts tension in the tensioning member.

17. The article of footwear according to claim **15**, wherein the user selects between the normal operating mode and the active operating mode.

18. The article of footwear according to claim **15**, wherein the user determines a second target tension, the second target tension having a substantially different tension than the first target tension.

19. The article of footwear according to claim **18**, wherein the control unit is configured to store the first target tension and the second target tension.

20. The article of footwear according to claim **15**, further comprising a pressure sensor disposed under an insole of the article of footwear.

* * * * *