An apparatus (100) for wrapping a load (138) with packaging material (142) may include a packaging material dispenser (140) for dispensing packaging material. The apparatus may also include a relative rotation assembly (129) for providing relative rotation between the load and the packaging material dispenser. The apparatus may further include a mechanical connection (133) operatively coupling the packaging material dispenser to the relative rotation assembly. The relative rotation assembly may be configured to drive the packaging material dispenser through the mechanical connection. The apparatus may further include a force exerting mechanism (181) operatively coupled to the mechanical connection. The apparatus may further include a sensing element (194) configured to sense a characteristic of dispensed packaging material. The sensing element may be operatively coupled to the mechanical connection. The force exerting mechanism and the sensing element may be configured to control the mechanical connection to maintain a selected ratio of packaging material dispensed to demand for packaging material at the load for at least a portion of a wrap cycle.
DEMAND THROTTLE METHODS AND APPARATUSES

Description

[001] This application claims priority under 35 U.S.C. § 119 based on U.S. Provisional Application No. 61/297,709, filed January 22, 2010, the complete disclosure of which is incorporated herein by reference.

Technical Field

[002] The present disclosure relates to methods and apparatuses for wrapping a load with packaging material, and more particularly, stretch wrapping.

Background

[003] Various packaging techniques have been used to build a load of unit products and subsequently wrap them for transportation, storage, containment and stabilization, protection and waterproofing. One system uses wrapping machines to stretch, dispense, and wrap packaging material around a load. The packaging material may be pre-stretched before it is applied to the load. Wrapping can be performed as an inline, automated packaging technique that dispenses and wraps packaging material in a stretch condition around a load on a pallet to cover and contain the load. Stretch wrapping, whether accomplished by a turntable, rotating arm, vertical rotating ring, or horizontal rotating ring, typically covers the four vertical sides of the load with a stretchable packaging material such as polyethylene packaging material. In each of these arrangements, relative rotation is provided between the load and a packaging material dispenser to wrap packaging material about the sides of the load.

[004] Wrapping machines provide relative rotation between a packaging material dispenser and a load either by driving the packaging material dispenser around a stationary load or rotating the load on a turntable. Upon relative rotation, packaging material is wrapped on the load. Rotating ring wrapping machines generally include a roll of packaging material mounted in a dispenser, which rotates about the load on a rotating ring. Rotating rings are categorized as vertical rotating
rings or horizontal rotating rings. Vertical rotating rings move vertically between an upper and lower position to wrap packaging material around a load. In a vertical rotating ring apparatus, as in turntable and rotating wrap arm apparatuses, the four vertical sides of the load are wrapped, along the height of the load. Horizontal rotating rings are stationary and the load moves through the rotating ring, usually on a conveyor, as the packaging material dispenser rotates around the load to wrap packaging material around the load. In a horizontal rotating ring apparatus, the length of the load is wrapped. As the load moves through the rotating ring and off the conveyor, the packaging material slides off a conveyor (the surface supporting the load) and into contact with the load.

[005] Historically, wrappers have suffered from packaging material breaks and limitations on the amount of force applied to the load (as determined in part by the amount of pre-stretch used) due to erratic speed changes required to wrap "non-square" loads, such as narrow, tall loads, short, wide loads, and short, narrow loads. The non-square shape of such loads often results in the supply of excess packaging material during the wrapping cycle, during time periods in which the demand rate for packaging material by the load is exceeded by the supply rate of the packaging material by the packaging material dispenser. This leads to loosely wrapped loads. In addition, when the demand rate for packaging material by the load is greater than the supply rate of the packaging material by the packaging material dispenser, breakage of the packaging material may occur.

[006] When wrapping a typical rectangular load, the demand for packaging material varies, decreasing as the packaging material approaches contact with a corner of the load and increasing after contact with the corner of the load. When wrapping a non-square load, the variation in the demand rate is even greater than in a typical rectangular load. In vertical rotating rings, high speed rotating arms, and turntable apparatuses, the variation is caused by a difference between the length and the width of the load. In a horizontal rotating ring apparatus, the variation is caused by a difference between the height of the load (distance above the conveyor) and the width of the load. Variations in demand may make it difficult to properly wrap the load. The problem with variations is exacerbated when wrapping a load having one or more dimensions that may differ from one or more corresponding dimensions of a preceding load. The problem may also be
exacerbated when wrapping a load having one or more dimensions that vary at one or more locations of the load itself.

[007] The amount of force, or pull, that the packaging material exhibits on the load determines how tightly and securely the load is wrapped. Conventionally, this wrap force is controlled by controlling the feed or supply rate of the packaging material dispensed by the packaging material dispenser, for example, the wrap force of many known commercially available stretch wrapping machines is controlled by attempting to alter the supply of packaging material such that a relatively constant packaging material wrap force is maintained. With powered pre-stretching devices, changes in the force or tension of the dispensed packaging material were monitored. This has been accomplished using feedback mechanisms typically linked to spring loaded dancer bars, electronic load cells, or torque control devices. The changing force or tension on the packaging material caused by rotating a rectangular shaped load is transmitted back through the packaging material to some type of sensing device which attempts to vary the speed of the motor driven dispenser to minimize the change. The passage of the corner causes the force or tension of the packaging material to increase. This increase is typically transmitted back to an electronic load cell, spring-loaded dancer interconnected with a sensing means, or to a torque control device. After the corner is passed, the force or tension on the packaging material reduces. This reduction is transmitted back to some device that in turn reduces the packaging material supply to attempt to maintain a relatively constant wrap force or tension.

[008] With the ever faster wrapping rates demanded by the industry, the rotation speeds have increased significantly to a point where the concept of sensing changes in force and altering supply speed in response loses effectiveness. The delay of response has been observed to begin to move out of phase with rotation at approximately 20 RPM. The actual response time for the rotating mass of packaging material roll and rollers approximating 100 lbs must shift from accelerate to decelerate eight times per revolution, that at 20 RPM, is a shift more than every half second.

[009] Even more significant is the need to minimize the acceleration and deceleration times for these faster cycles. Initial acceleration must pull against clamped packaging material, which typically cannot stand a high force, especially the high force of rapid acceleration that cannot be maintained by the feedback
mechanisms described above. Use of high speed wrapping has therefore been limited to relatively lower wrap forces and pre-stretch levels where the loss of control at high speeds does not produce undesirable packaging material breaks.

[010] Packaging material dispensers mounted on rotating rings present additional special issues concerning effectively wrapping at high speeds. Many commercially available rotating ring wrappers that are in use depend upon electrically powered motors to drive the pre-stretch packaging material dispensers. The power for these motors must be transmitted to the rotating ring. This is typically done through electric slip rotating rings mounted to the rotating ring with an electrical pick up fingers mounted to the fixed frame. Alternately others have attempted to charge a battery or run a generator during rotation. All of these devices suffer complexity, cost and maintenance issues. But even more importantly they add significant weight to the rotating ring which impacts its ability to accelerate and/or decelerate rapidly. Packaging material dispensers mounted on vertical rotating rings have the additional problem of gravity forces added to centrifugal forces of high-speed rotation.

[011] Accordingly, it is an object of the present disclosure to provide methods and apparatuses to overcome one or more of the above-identified disadvantages.

SUMMARY OF THE DISCLOSURE

[012] According to one aspect of the present disclosure, a method and apparatus for dispensing packaging material to be wrapped around a load is provided. The apparatus may include a packaging material dispenser including one or more packaging material dispensing rollers. The packaging material dispensing roller(s) may be driven to dispense packaging material by a rotational drive system through a mechanical connection operatively coupling the packaging material dispensing roller(s) and the rotational drive system.

[013] According to one aspect of the present disclosure, during at least a portion of a wrapping cycle, control of a mechanical connection operatively coupling a rotational drive system and a packaging material dispenser may be based at least in part on instantaneous demand for packaging material at the load. As used herein, the term "demand" may be defined as the quantity of packaging material
needed to wrap at least a portion of the load to achieve a desired wrap force and/or containment force sufficient to meet containment needs of the load. As used herein, wrap force is defined as the force exerted on the load by an individual web of film applied to the load. As used herein, containment force is defined as the force exerted on the load by cumulative layers of film. The containment force may be generated by the wrap forces exerted on the load by multiple layers of film. The term "instantaneous demand" may be defined as the demand for packaging material at a load at a particular instant. For a wrapping apparatus with a packaging material dispenser that rotates around a stationary load, the instantaneous demand may be represented by a line extending perpendicularly from the rotational axis of the packaging material dispenser to a plane defined by a surface of a length of packaging material that extends between the packaging material dispenser and the load. For a wrapping apparatus with a rotating load, instead of a rotating packaging material dispenser, the instantaneous demand may be represented by a line extending perpendicularly from the rotational axis of the load to the plane. Additionally or alternatively, the instantaneous demand may be represented by a line extending radially from the rotational axis of the packaging material dispenser to a point on the surface of the load (for a rotating packaging material dispenser), or by a line extending radially from the rotational axis of the load to a point on the surface of the load (for a rotating load).

[014] For example, as shown in FIG. 5, when the packaging material dispenser is in the position shown while wrapping a bottom portion of the load, the instantaneous demand at that instant may be represented by R1. When the packaging material dispenser is in the position shown while wrapping a middle portion of the load, the instantaneous demand at that instant may be represented by R2. Further, when the packaging material dispenser is in the position shown while wrapping a top portion of the load, the instantaneous demand at that instant may be represented by R3. Thus, it should be understood that for wrapping a load like the one shown in FIG. 5, the instantaneous demand may change during wrapping as the characteristics of the portion of the load being wrapped change. The varying profile of the load in FIG. 5 may be due to the load being composed of units that have different dimensions, girths, and/or shapes, that may be stacked together to form the load.
FIG. 8 shows representations of instantaneous demand for top, middle, and bottom portions of an irregularly shaped load when the packaging material dispenser is in the position shown. The instantaneous demand while wrapping the top portion may be represented by R4, the instantaneous demand while wrapping the middle portion may be represented by R5, and the instantaneous demand while wrapping the bottom portion may be represented by R6.

Even during portions of the wrapping cycle where the characteristics of the portion of the load being wrapped do not change, the instantaneous demand may change. For example, in FIG. 6, as the packaging material dispenser is wrapping the bottom portion of the load, when the packaging material dispenser is in the position shown, the instantaneous demand may be represented by R1. If the packaging material dispenser rotates in the counterclockwise direction, at a new position the instantaneous demand may be represented by a line R1'. R1' is shorter than R1, thus indicating that the instantaneous demand decreased as the packaging material dispenser traveled from the position shown to the new position. The instantaneous demand decreased even though the characteristics of the bottom portion of the load did not change. The change in instantaneous demand is due to the shape of the bottom portion of the load. The instantaneous demand will increase when the length of packaging material between packaging material dispenser and the load contacts a corner of the load, and may continue to increase for a period of time thereafter. However, as the length of the packaging material moves toward a face of load, the instantaneous demand will begin to decrease until the next corner is encountered.

Instantaneous demand can also be represented using by a distance from a suitable location, such as a point on the packaging material dispenser, to the load. Such distances are shown in FIG. 9. The distance may change during relative rotation between the packaging material dispenser and the load.

By controlling the mechanical connection operatively coupling the rotational drive system and the packaging material dispenser based at least in part on the instantaneous demand, adjustments can be made in response to the variations described above. By making such adjustments, it may be possible to reduce costs by decreasing the likelihood of film breaks and ensuring that excess packaging material is not dispensed; wrap a wide variety of loads regardless of
shape and/or size, or placement on a load wrapping surface; and improve throughput by allowing adjustments to settings to be made automatically. It may also be possible to obtain a more consistently wrapped load, since a selected payout percentage may be maintained for at least a portion of a wrapping cycle, and/or from one wrapping cycle to the next.

[019] As used herein, the phrase "payout percentage" is defined as a ratio of the amount of packaging material dispensed for at least a portion of a wrapping cycle to the demand for packaging material at the load for that same portion of the wrapping cycle. The payout percentage may be calculated or expressed in different ways. The payout percentage may be expressed as the percent of packaging material dispensed relative to at least a portion of load girth. For example, the payout percentage may be expressed as the percent of packaging material dispensed divided by load girth, wherein the packaging material dispensed is the amount for a full relative revolution between the packaging material dispenser and the load. Additionally or alternatively, the payout percentage may be expressed as the percent of packaging material dispensed divided by a portion of the load girth, wherein the packaging material dispensed is the amount for a portion of the relative revolution during which the portion of the load girth is wrapped. The portion of the load girth may be, for example, a portion between points A and B in FIG. 5, in which case the portion of the relative revolution is the half of the relative revolution during which the portion between points A and B is wrapped, and the packaging material dispensed for purposes of determining the payout percentage is the amount dispensed during that half of the relative revolution. The location of points A and B are intended to be exemplary only and points A and B may be located anywhere along the girth (perimeter) of the load.

[020] For example, if the length of packaging material dispensed is 100 inches, and the demand for packaging material at the load is 100 inches, then the payout percentage equals 100%. If the length of packaging material dispensed during a relative revolution is 130 inches, and the girth of the load is 100 inches, then the payout percentage equals 130%. Test results have shown that good wrapping performance in terms of load containment (wrap force), optimum packaging material use (efficiency), and avoiding film breaks, is obtained at a payout percentage that is between approximately 75% and approximately 130%, preferably between approximately 85% and approximately 120%, and more
preferably between approximately 95% and approximately 115%. Factors that may affect the results may include, for example, an amount the film is pre-stretched, the elasticity of the film, film gauge, film width, film quality, and gel level.

[021] The payout percentage may be selected based on the desired wrap force and/or containment force. For example, the payout percentage may be selected to produce a desired wrap force and/or containment force that may be sufficient to meet the containment needs of a load. The containment needs of a load may depend on the types of forces the load is exposed to during transport. Additionally or alternatively, the payout percentage may be selected based on the type of load being wrapped, taking into account factors, such as, the stability of the load, the crushability of the load, and/or any other suitable factors. Decreasing the payout percentage may cause the wrap force exerted by the packaging material on the load to increase (assuming other factors affecting wrap force remain constant), while increasing the payout percentage may cause the wrap force to decrease (assuming other factors affecting wrap force remain constant). The containment force may be generated by the wrap forces exerted on the load by multiple layers of film. A user may select payout percentages by setting or adjusting a force exerting mechanism operatively coupled to the mechanical connection that operatively couples the rotational drive system to the packaging material dispenser. It should be understood that a user may also select settings that correspond to a payout percentage without actually taking the payout percentage into consideration. For example, the user may select settings that are likely to produce good wrapping performance without actually having calculated the payout percentage, or considered values related to the payout percentage, to make the selection. The user may instead have selected the settings after, for example, experimenting with other settings, considering settings that produced good wrapping performance in the past, and/or selected the settings at random. To the extent that those settings are elements/indicators of payout percentage, by selecting those settings, the user will have selected a payout percentage.

[022] As used herein, the phrase "selected payout percentage" can be defined as a payout percentage at which a wrap force and/or containment force is achieved that is sufficient to meet the containment needs of a load, a range of payout percentages at which the wrap forces and/or containment forces achieved are within a range of values capable of meeting the containment needs of a load,
and/or a range of payout percentages that are within a range of ± 10%, preferably ± 7%, and more preferably ± 5% or less, of the payout percentage or range of payout percentages at which the containment needs of the load are met.

[023] In accordance with one aspect of the disclosure, an apparatus for wrapping a load with packaging material may include a packaging material dispenser for dispensing packaging material. The apparatus may also include a relative rotation assembly for providing relative rotation between the load and the packaging material dispenser. The apparatus may further include a mechanical connection operatively coupling the packaging material dispenser to the relative rotation assembly. The relative rotation assembly may be configured to drive the packaging material dispenser through the mechanical connection. The apparatus may further include a force exerting mechanism operatively coupled to the mechanical connection. The apparatus may further include a sensing element configured sense a characteristic of dispensed packaging material. The sensing element may be operatively coupled to the mechanical connection. The force exerting mechanism and the sensing element may be configured to control the mechanical connection to maintain a selected ratio of packaging material dispensed to demand for packaging material at the load for at least a portion of a wrap cycle.

[024] According to another aspect of the present disclosure, an apparatus for wrapping a load with packaging material may include a packaging material dispenser for dispensing packaging material. The apparatus may also include a relative rotation assembly for providing relative rotation between the load and the packaging material dispenser. The apparatus may further include a mechanical connection operatively coupling the packaging material dispenser to the relative rotation assembly. The relative rotation assembly may be configured to drive the packaging material dispenser through the mechanical connection. The apparatus may further include a sensing element configured to sense a change in demand for packaging material at the load and adjust the mechanical connection in response to the change in demand to maintain a ratio of packaging material dispensed to demand in a selected range for at least a portion of a wrap cycle.

[025] According to yet another aspect of the present disclosure, a method for wrapping a load with packaging material may include providing relative rotation between a packaging material dispenser and the load with a relative rotation
assembly. The method may also include driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection operatively coupling the packaging material dispenser and the relative rotation assembly. The method may further include engaging a portion of the packaging material extending between the packaging material dispenser and the load with a sensing element. A change of position of the sensing element may be indicative of a change in demand for packaging material at the load. The method may further include adjusting the mechanical connection based at least in part on movement of the sensing element to maintain a ratio of packaging material dispensed to demand in a selected range for at least a portion of a wrap cycle.

[026] According to yet another aspect of the present disclosure, a method for wrapping a load with packaging material may include providing relative rotation between a packaging material dispenser and the load with a relative rotation assembly. The method may also include driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection operatively coupling the packaging material dispenser and the relative rotation assembly. The method may further include controlling the mechanical connection with a sensing element operatively coupled to the mechanical connection. The method may further include engaging a portion of the packaging material extending between the packaging material dispenser and the load with the sensing element to monitor tension of the packaging material. The method may further include moving the sensing element to control the mechanical connection to maintain an amount of packaging material dispensed relative to the demand for packaging material at the load in a selected range for at least a portion of a wrapping cycle.

[027] According to yet another aspect of the present disclosure, a method for wrapping a load with packaging material may include providing relative rotation between a packaging material dispenser and the load with a relative rotation assembly. The method may also include driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection operatively coupling the packaging material dispenser and the relative rotation assembly. The method may further include engaging a portion of the packaging material extending between the dispensing assembly and the load with a sensing element operatively coupled to a control element of the mechanical
connection. The method may further include exerting a force on the control element with an adjustable force exerting mechanism. The method may further include controlling the mechanical connection with the control element, through positioning of the sensing element and the force exerted by the adjustable force exerting mechanism, to maintain a ratio of packaging material dispensed relative to demand for packaging material at the load substantially constant for at least a portion of a wrap cycle.

[028] According to yet another aspect of the present disclosure, an apparatus for stretch wrapping a load may include a packaging material dispenser for dispensing packaging material. The packaging material dispenser may include a dispensing assembly for pre-stretching the packaging material. The apparatus may also include a relative rotation assembly for providing relative rotation between the load and the packaging material dispenser. The apparatus may further include a mechanical connection operatively coupling the dispensing assembly to the relative rotation assembly. The relative rotation assembly may be configured to drive the dispensing assembly through the mechanical connection. The apparatus may further include a sensing roller configured to sense a change in demand for packaging material at the load, and move to adjust the mechanical connection in response to the change in packaging material demand. The apparatus may further include an adjustable force exerting mechanism operatively coupled to the sensing roller. The adjustable force exerting mechanism may be configured to control movement of the sensing roller.

[029] According to yet another aspect of the present disclosure, an apparatus for wrapping a load with packaging material may include a packaging material dispenser for dispensing packaging material. The apparatus may also include a relative rotation assembly for providing relative rotation between the load and the packaging material dispenser. The apparatus may further include a mechanical connection operatively coupling the packaging material dispenser to the relative rotation assembly. The relative rotation assembly may be configured to drive the packaging material dispenser through the mechanical connection. The apparatus may further include a force exerting mechanism operatively coupled to the mechanical connection. The apparatus may further include a sensing element configured sense a characteristic of dispensed packaging material. The sensing element may be operatively coupled to the mechanical connection. The force
exerting mechanism and the sensing element may be configured to control the mechanical connection to maintain a wrap force exerted by the dispensed packaging material on the load in a selected force range for at least a portion of a wrap cycle.

[030] Additional objects and advantages of the disclosure will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the disclosure. The objects and advantages of the disclosure will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[031] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosure, as claimed.

[032] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the disclosure and together with the description, serve to explain the principles of the disclosure.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[033] FIG. 1 is an isometric view of a wrapping apparatus for wrapping a load, according to one aspect of the present disclosure;

[034] FIG. 2 is an isometric view of a roll carriage of the wrapping apparatus of FIG. 1, according to one aspect of the present disclosure;

[035] FIG. 3 is an enlarged portion of the isometric view of the roll carriage of FIG. 2;

[036] FIG. 4 is an isometric view of a support structure for the rotating ring of a wrapping apparatus according to one aspect of the present disclosure;

[037] FIG. 5 is a top view of a roll carriage and a load, according to one aspect of the present disclosure;

[038] FIG. 6 is a side view of the load of FIG. 5, according to the present disclosure.

[039] FIG. 7 is an enlarged portion of the isometric view of the roll carriage of FIG. 2;

[040] FIG. 8 is a top view of a roll carriage and a load, according to another aspect of the present disclosure;
FIG. 9 is a top view of a roll carriage and a load, according to yet another aspect of the present disclosure;

FIG. 10 is an isometric view of a roll carriage of a wrapping apparatus, according to another aspect of the present disclosure; and

FIG. 11 is an enlarged portion of the isometric view of the roll carriage of FIG. 10.

DESCRIPTION OF THE EMBODIMENTS

Reference will now be made in detail to the present embodiments of the disclosure, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.


[046] The present disclosure is related to a method and apparatus for dispensing packaging material to be wrapped around a load. In an exemplary embodiment, packaging material is stretch wrap packaging material. As used herein, stretch wrap packaging material is defined as material having a high yield coefficient to allow the material a large amount of stretch during wrapping. However, it is possible that the apparatuses and methods disclosed herein may be practiced with packaging material that will not be pre-stretched prior to application to the load. Examples of such packaging material include netting, strapping, banding, or tape. As used herein, the terms "packaging material," "film," "film web," "web," and "packaging material web" are interchangeable.

[047] According to one aspect of the present disclosure, a wrapping apparatus 100 for wrapping packaging material 142 around a load 138, shown in FIG. 1, may include a non-rotating frame 110 having four legs, 112a, 112b, 112c, and 112d. A movable frame portion 118 may be connected to and movable on the non-rotating frame 110. Movable frame portion 118 may include a support portion 120, a rotatable ring 122, and a support structure 124, shown in FIGS. 2-4. Support structure 124 may include, for example, a fixed (i.e., non-rotatable) ring, a curved portion that is discontinuous, one or more finger-type supports, support rollers, a belt supporting track, and/or any other suitable support structure known in the art. It is also contemplated that non-rotating frame 110, support portion 120, rotatable ring 122, and support structure 124 may be similar to the non-rotating frame, support portion, rotatable ring, and fixed ring described in U.S. Patent Application Publication No. 2007/0204565, entitled "METHOD AND APPARATUS FOR METERED PRE-STRETCH FILM DELIVERY," filed February 23, 2007, the entire disclosure of which is incorporated herein by reference in its entirety.

[048] A first drive belt 130, shown in FIGS. 1-3, driven by a motor 132, may be positioned around an outer circumference of rotatable ring 122. Motor 132 rotates first drive belt 130 which in turn rotates rotatable ring 122. Thus, motor 132 and first drive belt 130 form a rotational drive system 129. Alternatively, rotatable ring 122 can be frictionally driven by one or more suitably surfaced wheels pressed against its outer surface.
Wrapping apparatus 100 may include a roll carriage 144 similar to the one described in U.S. Patent Application Publication No. 2007/0204565, filed February 23, 2007, the entire disclosure of which is incorporated herein by reference in its entirety. Roll carriage 144 may be mounted on rotatable ring 122. Roll carriage 144 and rotatable ring 122 may rotate about a vertical axis 158 (FIG. 1) as moveable frame portion 118 moves up and down the non-rotating frame 110 to spirally wrap packaging material 142 about a load 138. A motor 136 may be provided to raise and/or lower moveable frame portion 118 on non-rotating frame 110. Load 138 can be manually placed in the wrapping area or conveyed into the wrapping area by a conveyor (not shown). As shown in FIGS. 1-3, roll carriage 144 may be mounted underneath and outboard of rotatable ring 122, thus maximizing wrapping space. Roll carriage 144 may include a packaging material dispenser 140, as shown in FIGS. 1-3, 5, and 8-11. Packaging material dispenser 140 may include a dispensing assembly 160 configured to dispense a sheet or web of packaging material 142.

Dispensing assembly 160 may be driven to dispense packaging material 142 by rotational drive system 129, through a path 131 and a mechanical connection 133 operatively connecting rotational drive system 129 and dispensing assembly 160. Path 131 may include a second drive belt 134, shown in FIGS. 1-4. Second drive belt 134 may be supported by support structure 124. For example, second drive belt 134 may be positioned around the outer circumference of support structure 124. Second drive belt 134 may include a fixed belt, drive chain, or other suitable device, that does not rotate. Additionally or alternatively, a rotatable or non-rotatable drive ring may be provided, and may be supported by support structure 124. Additionally or alternatively, path 131 may include components similar to those disclosed in U.S. Patent Application Publication No. 2007/0204565, entitled "METHOD AND APPARATUS FOR METERED PRE-STRETCH FILM DELIVERY," and filed September 6, 2007, incorporated herein by reference in its entirety, to link a relative rotation assembly and a dispensing assembly of a packaging material dispenser.

Mechanical connection 133 may include, for example, a mechanical ratio control 192 operatively coupled to path 131 and dispensing assembly 160. As shown in FIGS. 2 and 3, mechanical ratio control 192 may include a variable transmission such as, for example, a hydrostatic transmission 200. One exemplary...
such hydrostatic transmission is made by Hydrogear, model number BDR-311. Hydrostatic transmission 200 may be supported on roll carriage 144, and may include a rotatable input shaft 202 and a rotatable output shaft 204. A series of hydraulic pumps and valves (not shown) are used to set the ratio between the input and the output of hydrostatic transmission 200. This ratio may be set and adjusted as desired. The hydraulic pumps and valves set the ratio based on fluid flow in hydrostatic transmission 200, rather than based on fluid pressure in hydrostatic transmission 200.

[052] Second drive belt 134 may engage rotatable input shaft 202 of hydrostatic transmission 200. Rotatable input shaft 202 of hydrostatic transmission 200 may engage second drive belt 134 through gear teeth or any other suitable mode of engagement.

[053] Although a hydrostatic transmission is used in the exemplary embodiment, any other appropriate mechanical power transmissions may be used to control the input/output ratio. Further, other suitable mechanical controls such as, for example, a split sheave, variable pitch belt sheaves, fixed center and adjustable center sheaves, wider range variable pitch belt drives, cone and ring variable speed drives, rolling ring variable speed drives, and ball and ring variable speed drives may be used to control the input/output ratio. Alternatively, methods such as a moving a second ring with the differential between the rings generating the output, moving second drive belt 134 with the differential between second drive belt 134 and rotatable ring 122 generating the output, using a differential and controlling one output to adjust another output, and an electric motor without load cell feedback may be used.

[054] Dispensing assembly 160 may be configured to pre-stretch packaging material 142 before it is applied to load 138 if pre-stretching is desired, or to dispense packaging material 142 to load 138 without pre-stretching. Dispensing assembly 160 may include a packaging material dispensing roller, such as a downstream dispensing roller 164, or a plurality of packaging material dispenser rollers, such as an upstream dispensing roller 162 and downstream dispensing roller 164. It is also contemplated that dispensing assembly 160 may include an assembly of pre-stretch rollers and idle rollers, similar to those described in U.S. Patent Application Publication Nos. 2006/0248858, 2007/0204565, 2007/0204564, and 2009/0178374, the disclosures of which are incorporated herein by reference.
in their entirety. Additional or fewer rollers may be used as desired. In one exemplary embodiment, each of upstream and downstream dispensing rollers 162, 164 may preferably be the same size, and each may have, for example, an outer diameter of approximately 2.5 inches. Upstream and downstream dispensing rollers 162, 164 should have a sufficient length to carry a twenty inch wide web of packaging material 142 along their working lengths. It is contemplated that, in one exemplary embodiment, rollers used for conventional conveyors may be used to form upstream and downstream dispensing rollers 162, 164.

[055] The terms "upstream" and "downstream," as used in this application, are intended to define positions and movement relative to the direction of flow of packaging material 142 as it moves from packaging material dispenser 140 to load 138. Movement of an object toward packaging material dispenser 140, away from load 138, and thus, against the direction of flow of packaging material 142, may be defined as "upstream." Similarly, movement of an object away from packaging material dispenser 140, toward load 138, and thus, with the flow of packaging material 142, may be defined as "downstream." Also, positions relative to load 138 and packaging material dispenser 140 may be described relative to the direction of packaging material flow. For example, when two dispensing rollers are present, the dispensing roller closer to packaging material dispenser 140 may be characterized as the "upstream" roller and the dispensing roller closer to load 138 and further from packaging material dispenser 140 may be characterized as the "downstream" roller.

[056] The surfaces of upstream dispensing roller 162 and downstream dispensing roller 164 may either be coated or uncoated depending on the type of application in which wrapping apparatus 100 is being used. Upstream and downstream dispensing rollers 162, 164 may be mounted on roller shafts 166 and 168, respectively. Roller shafts 166 and 168 may include, for example, hex shafts. Sprockets 170 and 172 may be located on the ends of the roller shafts 166 and 168, respectively, and may be configured to provide control over the rotation of roller shafts 166 and 168, and thus, upstream and downstream dispensing rollers 162, 164. Upstream and downstream dispensing rollers 162, 164, may be operatively connected to each other through a drive belt or chain 174 connecting sprockets 170 and 172.
[057] It is contemplated that upstream dispensing roller 162 and downstream dispensing roller 164 may have different sized sprockets 170 and 172 so that the surface movement of upstream dispensing roller 162 may be slower than that of downstream dispensing roller 164. For example, sprockets 170 and 172 may be sized so that the surface movement of upstream dispensing roller 162 is at least approximately 40% slower than that of downstream dispensing roller 164. Sprockets 170, 172 may be sized depending on the amount of packaging material elongation desired. Thus, the surface movement of upstream dispensing roller 162 can be about 40%, 75%, 200% or 300% slower than the surface movement of downstream dispensing roller 164 to obtain pre-stretching of 40%, 75%, 200% or 300%. While pre-stretching normally ranges from 40% to 300%, excellent results have been obtained when narrower ranges of pre-stretching are used, such as pre-stretching the material 40% to 75%, 75% to 200%, 200% to 300%, and at least 100%. In certain instances, pre-stretching has been successful at over 300% of pre-stretch.

[058] Rapid elongation of packaging material 142 by upstream and downstream dispensing rollers 162, 164, followed by rapid strain relief of packaging material 142, may cause a "memorization" effect. Due to this "memorization" effect, packaging material 142 may continue to shrink for some time after being wrapped onto load 138. Over time, packaging material 142 may significantly increase its holding force and conformation to load 138. This characteristic of packaging material 142 may allow it to be used for wrapping loads at very close to zero stretch wrapping force, using the memory to build holding force and load conformity. Some embodiments of the present disclosure permit relative rotation between the load and dispenser at approximately 60 rpm. At this speed, the dispensed pre-stretched film has a tendency to billow around the load before contracting and/or shrinking onto the load such that the film contacts all sides and/or corners of the load substantially simultaneously. This is particularly beneficial when dealing with light, crushable, or twistable loads.

[059] During operation of apparatus 100, motor 132 drives first drive belt 130, which in turn rotates rotatable ring 122, roll carriage 144 mounted on rotatable ring 122, and hydrostatic transmission 200 supported by roll carriage 144. As hydrostatic transmission 200 rotates with ring 122, second drive belt 134 on support structure 124 engages rotatable input shaft 202 of hydrostatic transmission 200,
causing rotatable input shaft 202 to rotate. Thus, second drive belt 134 translates the rotational drive from rotatable ring 122 to input shaft 202 of hydrostatic transmission 200. Using one or more pumps and/or valves, hydrostatic transmission 200 converts movement of input shaft 202 into fluid flow toward the output of hydrostatic transmission 200, and converts the fluid flow into movement of output shaft 204. Since hydrostatic transmission 200 operates based on fluid flow, rather than based on fluid pressure, the lag time associated with building up fluid pressure and/or decreasing fluid pressure, to create a desired output, may be avoided. Instead, by operating based on fluid flow, hydrostatic transmission 200 can provide an immediate response of output shaft 204 due to movement of input shaft 202.

[060] The output of hydrostatic transmission 200, via rotatable output shaft 204, drives downstream dispensing roller 164, and through connection 174, upstream dispensing roller 162. As upstream and downstream dispensing rollers 162, 164 rotate, packaging material 142 flows downstream from packaging material roll 152 through dispensing assembly 160. By using second drive belt 134 to drive dispensing assembly 160 off of rotatable ring 122, and thus, rotational drive system 129, it is possible to eliminate the conventional motor that drives known packaging material dispensers, as well the conventional control box, greatly reducing the weight of packaging material dispenser 140. By providing a mechanical connection between the rotational drive system and dispensing assembly 160, the need for placing electrical power sources or connections on rotatable ring 122 for electrically powering the dispensing assembly 160 may be eliminated. It is contemplated that the mechanical connection may be entirely mechanical, devoid of any components that operate using electrical power, or at least partially mechanical, with one or more components that operate using electrical power, including, for example, a servocontrol device.

[061] The rotation of rotatable output shaft 204 drives downstream dispensing roller 164. Connection 174 between the upstream and downstream dispensing rollers 162, 164 causes upstream dispensing roller 162 to rotate as downstream dispensing roller 164 rotates, thus dispensing packaging material 142. Engagement between rotatable output shaft 204 and downstream dispensing roller 164 may include, for example, drive belts, gears, chains, and/or any other suitable devices configured to convert rotation of rotatable output shaft 204 into rotation of
upstream and downstream dispensing rollers 162, 164. In the exemplary embodiment, hydrostatic transmission 200 may have a ninety degree angle between its rotatable input shaft 202 and its rotatable output shaft 204.

[062] Hydrostatic transmission 200 may be set to control a ratio of the relative rotational speed to dispensing speed by controlling a ratio of drive input to drive output. The speed at which rotatable input shaft 202 rotates, based on the speed at which rotational drive system 129 rotates rotatable ring 122 and roll carriage 144, may be considered the input. The series of pumps and valves contained within hydrostatic transmission 200 transmit the input from rotatable input shaft 202 to rotatable output shaft 204 using fluid flow, adjusting the rotational speed of rotatable output shaft 204 based on the input/output ratio of hydrostatic transmission 200. The input/output ratio of hydrostatic transmission 200 may be selectively and variably adjusted. As the input/output ratio decreases, the relative speed of the output shaft 204 increases, and the rotational speed of upstream and downstream dispensing rollers 162, 164 increases proportionally. The increased rotational speed of upstream and downstream dispensing rollers 162, 164 causes an increase in the supply/dispensing rate of packaging material 142. If, on the other hand, the input/output ratio increases, then the speed of the rotational output shaft 204 decreases, and the relative rotational speed of upstream and downstream dispensing rollers 162, 164 decreases proportionally, resulting in a decrease in the supply/dispensing rate of packaging material 142. Thus, it should be apparent that while rotatable ring 122 and the rotatable input shaft may rotate at substantially the same speed, the rotational speed of rotatable output shaft 204, and consequently the rotational speed of upstream and downstream dispensing rollers 162, 164, may vary depending on the input/output ratio setting of hydrostatic transmission 200.

[063] The input/output ratio setting of hydrostatic transmission 200 may be selectively and variably adjusted by a transmission lever 206 or other suitable control element operatively coupled to hydrostatic transmission 200. The orientation of transmission lever 206 may affect the input/output ratio of hydrostatic transmission 200. That is, changing the position of transmission lever 206 may change the input/output ratio of hydrostatic transmission 200. This adjustment of the input/output ratio may be accomplished, for example, by controlling a valve positioned between an input pump and an output pump in hydrostatic transmission.
200. Rotation of transmission lever 206 in a first direction may decrease the input/output ratio by increasing fluid flow between the input and output sides of hydrostatic transmission 200. Continued rotation of transmission lever 206 in the first direction may bring transmission lever 206 into a first position, where substantially all of the input at rotatable input shaft 202 may be transmitted or translated to rotatable output shaft 204. Rotation of transmission lever 206 in a second direction may increase the input/output ratio by decreasing the fluid flow between the input and output sides of hydrostatic transmission 200. Continued rotation of transmission lever 206 in the second direction may bring transmission lever to a second position, where transmission or translation of the input at rotatable input shaft 202 to rotatable output shaft 204 is prevented. When input at rotatable input shaft 202 is prevented from being transmitted/translated to rotatable output shaft 204, hydrostatic drive 200 is essentially in a neutral state wherein rotation of rotatable input shaft 202 is not transmitted to rotatable output shaft 204. In that state, rotatable input shaft 202 may rotate freely and independently of rotatable output shaft 204, and rotatable output shaft 204 may stop rotating.

[064] The use of hydrostatic transmission 200 may provide advantages. One advantage is the input/output ratio of hydrostatic transmission 200 is infinitely or continuously variable in a range defined by the first and second positions of transmission lever 206. Thus, since hydrostatic transmission 200 is used to control dispensing of packaging material 142 through its connection to downstream dispensing roller 164, hydrostatic transmission 200 allows for fine tuning of how much packaging material 142 is dispensed during at least a portion of a wrap cycle, that cannot be achieved with conventional gear and sprocket assemblies, which typically operate at only a few discrete states. Another advantage is that hydrostatic transmission 200 is highly sensitive, in that only about two to three pounds of force may be required to move transmission lever 206 between its first and second positions. Thus, hydrostatic transmission 200 may respond to smaller changes in the force on packaging material 142 than conventional gear and sprocket assemblies. Yet another advantage is that hydrostatic transmission 200 can offer instantaneous power to rotate downstream dispensing roller 164, and if pre-stretching is desired, upstream dispensing roller 162. For example, if hydrostatic drive 200 is in neutral, input shaft 202 may continue to rotate due to its movement relative to second drive belt 134, while output shaft 204 may receive
none of the power from input shaft 202. However, as soon as transmission lever 206 begins to move in the first direction (away from neutral), the power from the already rotating input shaft 202 is immediately available, and may instantaneously be transmitted to output shaft 204 for use by upstream and downstream dispensing rollers 162, 164 to dispense packaging material 142. The immediately availability of the power from input shaft 202 is due to hydrostatic transmission 200 using fluid flow, as opposed to fluid pressure, to transmit power to output shaft 204, since systems that use fluid pressure require lag time in order for the fluid pressure to build and/or release to achieve a desired output. Moreover, changes in power transmission between input shaft 202 and output shaft 204 may occur smoothly as the valve in hydrostatic transmission 200 opens and closes, ensuring smooth wrapping, and reducing chatter associated with conventional gear and sprocket assemblies.

[065] While the position of transmission lever 206 may dictate the input/output ratio of hydrostatic transmission 200, a sensing element 194 may move transmission lever 206, causing a change in the position of transmission lever 206, and thus, sensing element 194 may affect change in the input/output ratio of hydrostatic transmission 200. Sensing element 194 may be operatively coupled to transmission lever 206 through a series of linkages 197. Sensing element 194 may include a sensing roller 195 mounted for rotation on a shaft 212. Sensing roller 195 may have an outer diameter of, for example, approximately 2.5 inches, and may have a sufficient length to carry a twenty inch wide web of packaging material 142 along its working length. Sensing roller 195 may have other dimensions as appropriate. In one embodiment, bearings for supporting shaft 212 may be press-fit or welded into each end of sensing roller 195, and shaft 212 may be placed therethrough, such that shaft 212 may be centrally and axially mounted through the length of sensing roller 195. A first end of shaft 212 may extend through a slot 214 in a lower frame portion 216 of roll carriage 144, and may be pivotally attached to an upper support plate 218 of roll carriage 144. Additionally, shaft 212 may be cantilevered, such that a second end of the shaft may hang freely. Consequently, sensing roller 195 may have the ability to swing back and forth between an extended position (generally away from dispensing assembly 160) and a retracted position (generally toward dispensing assembly 160). Alternatively, it is contemplated that sensing element 194 may include a bar (not shown) pivotally
attached to roll carriage 144, over which packaging material 142 may slide, an assembly including one or more wheels (not shown), mounted on shaft 212 and configured to engage packaging material 142, and/or any other suitable devices for engaging packaging material 142. Sensing element 194 may be configured to sense one or more characteristics of packaging material 142, including, for example, the tension force exerted on sensing element 194 by packaging material 142, the orientation of packaging material 142 relative to load 138, and/or any other suitable characteristics.

[066] The swinging movement of sensing element 194 may rotate transmission lever 206 through linkages 197. As sensing element 194 swings toward its extended position, transmission lever 206 may rotate in its second direction, the one that increases the input/output ratio of hydrostatic transmission 200. This may cause the relative rotational speed of upstream and downstream dispensing rollers 162, 164 to decrease proportionally, resulting in a decrease in the supply rate of packaging material 142. As sensing element 194 swings toward its retracted position, transmission lever 206 may rotate in its first direction, the one that decreases the input/output ratio of hydrostatic transmission 200. This may cause the relative rotational speed of upstream and downstream dispensing rollers 162, 164 to increase proportionally, resulting in an increase in the supply rate of packaging material 142. Thus, the angular orientation of sensing element 194 may affect the amount of film dispensed during at least a portion of a revolution of roll carriage 144 relative to load 138. As described below, a force exerting mechanism 181 and tension in packaging material 142 may affect the angular orientation of sensing element 194, and thus, also may affect the amount of film dispensed during the at least a portion of the revolution.

[067] Force exerting mechanism 181 may include a spring device 183. As shown in FIG. 7, a first end 184 of spring device 183 may be coupled to shaft 212 of sensing element 194. A second end 186 of spring device 183 may be coupled to a frame portion 185. Frame portion 185 may extend from lower frame portion 216. Spring device 183 may exert a force on shaft 212 in a direction that moves sensing element 194 toward its extended position. Thus, unless it is overcome by a greater opposing force, the force exerted by spring device 183 will pull sensing element 194 toward its extended position.
[068] During normal operation of wrapping apparatus 100, tension in packaging material 142 may exert a force on sensing element 194 in a direction that moves sensing element 194 toward its retracted position. Thus, unless it is counteracted by a greater opposing force, the tension force exerted by packaging material 142 will pull sensing element 194 towards it retracted position. Accordingly, the force exerted by spring device 183 and the tension force exerted by packaging material 142 may oppose one another.

[069] The instantaneous demand and the tension force exerted by packaging material 142 on sensing element 194 are linked. During wrapping, changes in the tension force exerted by packaging material 142 on sensing element 194 may be caused by changes in instantaneous demand for packaging material 142 at load 138. For example, an increase in the instantaneous demand produces an increase in the tension force. A decrease in the instantaneous demand produces a corresponding decrease in the tension force. Thus, sensing element 194, by responding to changes in the tension force during wrapping, also responds to changes in the instantaneous demand. As the instantaneous demand increases (producing an increase in the tension force), sensing element 194 may be pulled toward its retracted position (e.g., toward the uppermost position shown in dashed lines in FIG. 5), thus increasing the supply rate of packaging material 142. As the instantaneous demand decreases (producing a decrease in the tension force), sensing element 194 may be pulled toward its extended position (e.g., toward the lowermost position shown in dashed lines in FIG. 5), thus decreasing the supply rate of packaging material 142. This is described in more detail below.

[070] If, on the one hand, the tension force exceeds the force exerted by force exerting mechanism 181, sensing element 194 will be pulled in the direction of the tension force (i.e., toward its retracted position). Through linkages 197 and transmission lever 206, movement of sensing element 194 toward its retracted position will decrease the input/output ratio of hydrostatic transmission 200, thus increasing the speed of upstream and downstream dispensing rollers 162, 164 proportionally, resulting in an increase in the supply rate of packaging material 142. As sensing element 194 is pulled toward its retracted position, the difference between the tension force and the force exerted by force exerting mechanism 181 may begin to decrease. Reasons for the decrease may include the following: movement of sensing element 194 toward its retracted position and/or the increase
in the supply rate may alleviate some of the tension in packaging material 142; movement of sensing element 194 toward its retracted position may stretch spring device 183, thus increasing the force spring device 183 is capable of exerting; and/or continued relative rotation between roll carriage 144 and load 138 may bring packaging material dispenser 140 to a point of the wrapping cycle where there is a decrease in instantaneous demand for packaging material 142 at load 138 (as will be described below). As the difference between the tension force and the force exerted by spring device 183 begins to decrease, movement of sensing element 194 toward its retracted position will slow down. If a point is reached where the force exerted by spring device 183 once again substantially equals the tension force, sensing element 194 will stop moving toward the retracted position. The new position of sensing element 194 will correspond to a greater supply rate of packaging material 142 than the position of sensing element 194 before the increase in the tension force.

[071] If, on the other hand, the tension force falls below the force exerted by spring device 183, sensing element 194 will be pulled in the direction of the force exerted by spring device 183 (i.e., toward its extended position). Through linkages 197 and transmission lever 206, movement of sensing element 194 toward its extended position will increase the input/output ratio of hydrostatic transmission 200, thus decreasing the speed of upstream and downstream dispensing rollers 162, 164 proportionally, resulting in a decrease in the supply rate of packaging material 142. As sensing element 194 is pulled toward its extended position, the difference between the tension force and the force exerted by spring device 183 may begin to decrease. Reasons for the decrease may include the following: movement of sensing element 194 toward its extended position and/or the decrease in the supply rate may increase the tension in packaging material 142; spring device 183 may contract as sensing element 194 moves toward its extended position, and thus, the force spring device 183 is capable of exerting may decrease; and/or relative rotation between roll carriage 144 and load 138 may bring packaging material dispenser 140 to a point of the wrapping cycle where there is an increase in the instantaneous demand for packaging material 142 at load 138 (as will be described below). As the difference between the tension force and the force exerted by spring device 183 begins to decrease, movement of sensing element 194 toward its extended position will slow down. When a point is reached where
the force exerted by spring device 183 once again substantially equals the tension force, sensing element 194 will stop. The new position of sensing element 194 will correspond to a lesser supply rate of packaging material 142 than the position of sensing element 194 before the decrease in the tension force.

[072] Thus, it should be apparent that because the tension force and force exerted by spring device 183 determine the position of sensing element 194, then the tension force and force exerted by spring device 183 also determine the supply rate of packaging material 142 during wrapping. By controlling the supply rate of packaging material 142 based at least in part on the tension force, and thus, the instantaneous demand for packaging material 142 at load 138, a selected payout percentage may be maintained for at least a portion of a wrap cycle, even though characteristics of load 138 may change. That is, the selected payout percentage may be maintained for at least a portion of a wrap cycle even as demand for packaging material at load 138 varies. It should be understood that while the selected payout percentage may be maintained, it does not necessarily mean that a wrap force exerted on load 138 by packaging material 142 is maintained or leveled, and in some instances, while the selected payout percentage remains relatively constant, the wrap force may not, but rather, may vary to a higher degree than the selected payout percentage during wrapping.

[073] For example, when load 138 of FIGS. 5 and 6 is being wrapped, the instantaneous demand for packaging material 142 at load 138 may change numerous times during wrapping. When the instantaneous demand increases, such as when packaging material dispenser 140 moves from wrapping top portion 145 to middle portion 143, or middle portion 143 to bottom portion 141, or when packaging material dispenser 140 wraps a corner of load 138 after having wrapped a flat surface of load 138, the increase in the instantaneous demand will cause an increase in the tension force exerted on sensing element 194 by packaging material 142. The increase in the tension force will pull sensing element 194 toward its retracted position. Movement of sensing element 194 produces an immediate response from hydrostatic transmission 200 in the form of increased fluid flow from its input to its output, thus increasing the supply rate of packaging material 142, and increasing the amount of dispensed packaging material 142. The additional amount of packaging material 142 dispensed may compensate for the increase in instantaneous demand, keeping the payout percentage substantially...
constant and/or in line with the selected payout percentage. By keeping the payout percentage substantially constant and/or in line with the selected payout percentage, it is contemplated that the wrap force and/or containment force may remain substantially constant and/or in a selected range. The immediate response of hydrostatic transmission 200 may help to ensure that spikes in instantaneous demand for packaging material 142 do not cause breaks in packaging material 142, by addressing increases in demand immediately.

[074] Whether the payout percentage remains substantially constant and/or in line with the selected payout percentage may be determined in any number of ways. For example, it is contemplated that a counter (not shown) may be coupled to at least one roller, such as, for example, downstream dispensing roller 164 and/or an idle roller engaging dispensed packaging material 142. The counter may be configured to count the number of revolutions undergone by the at least one roller during at least a portion of a wrap cycle. That count may be divided by the number of revolutions undergone by packaging material dispenser 140 during the portion of the wrap cycle to determine the number of counts per revolution. Since the circumference of the at least one roller can be easily measured, the dispensed film per revolution of packaging material dispenser 140 can be calculated based on the number of counts, and that dispensed film per revolution can be compared to the measured girth of load 138 to determine the payout percentage. The determined payout percentage may be compared to the selected payout percentage. The process may be repeated during another portion of the wrap cycle, to determine if and how much the payout percentage has changed between portions of the wrap cycle.

[075] When the instantaneous demand decreases during wrapping, such as when packaging material dispenser 140 moves from wrapping bottom portion 141 to middle portion 143, or middle portion 143 to top portion 145, or when packaging material dispenser 140 wraps a flat surface of load 138 after having wrapped a corner of load 138, the decrease in the instantaneous demand will cause a decrease in the tension force exerted on sensing element 194 by packaging material 142. The decrease in the tension force will allow sensing element 194 to be pulled toward its extended position by spring device 138. Movement of sensing element 194 produces an immediate response from hydrostatic transmission 200 in the form of decreased fluid flow from its input to its output, thus decreasing the
supply rate of packaging material 142, and decreasing the amount of packaging material 142 dispensed. The decreased amount of dispensed packaging material 142 may compensate for the decrease in instantaneous demand, once again keeping the payout percentage substantially constant and/or in line with the selected payout percentage.

[076] If the sensed decrease in the instantaneous demand is caused, for example, by a partial break in packaging material 142, the response of hydrostatic transmission 200 may be proportional to the sensed decrease in the instantaneous demand. That is, hydrostatic transmission 200 will not immediately discontinue dispensing of packaging material 142 upon sensing a decrease in instantaneous demand, allowing the partially broken length of packaging material 142 to reach load 138, after which unbroken packaging material 142 can once again be dispensed onto load 138. As such, downtime associated with full packaging material breaks can be reduced or avoided. If, on the other hand, packaging material dispensing was immediately and fully discontinued upon sensing of a decrease in instantaneous demand, relative rotation between packaging material dispenser 140 and load 138 would put additional stress on packaging material 142, which could cause the partial break to become a full break.

[077] It is also contemplated that if, after load 138 is wrapped, the subsequent load to be wrapped has a size and/or shape that is different from the size or shape of load 138, the payout percentage may remain at substantially the same level, and/or in line with the selected payout percentage, during wrapping of the subsequent load. For example, if the subsequent load is larger than load 138, there will be a greater instantaneous demand for packaging material 142 at the subsequent load. The increase in instantaneous demand, through its effect on the position of sensing element 194, will result in an increase in the supply rate of packaging material 142. Thus, the payout percentage may remain substantially unchanged, and/or in line with the selected payout percentage, as the amount of packaging material 142 dispensed rises to meet the increase in the instantaneous demand. If, on the other hand, the subsequent load is smaller than load 138, there will be a smaller instantaneous demand for packaging material 142 at the subsequent load. The decrease in instantaneous demand, through its effect on sensing element 194, will result in a decrease in the supply rate of packaging material 142. Thus, once again, the payout percentage may remain substantially
unchanged, and/or in line with the selected payout percentage, as the amount of
packaging material 142 dispensed falls to meet the decrease in the instantaneous
demand. It should be understood that under any of the above-described
circumstances, a change in instantaneous demand for packaging material 142 at
load 138, or any other load to be wrapped, regardless of size, shape, or orientation,
may result in a proportional change in the supply rate and amount of film
dispensed, such that the payout percentage may nevertheless remain substantially
constant and/or in line with the selected payout percentage.

[078] Force exerting mechanism 181 may include an adjustment assembly
187, as shown in FIG. 7, for selectively and variably setting a force gradient acting
on sensing element 194, and thus, setting the selected payout percentage which,
as described above, may be maintained for at least a portion of a wrap cycle. The
force gradient may be set by adjusting the initial force that spring device 183 is
capable of exerting on sensing element 194. Once the selected payout percentage
has been set, it may be maintained for at least a portion of a wrapping cycle, or
even during multiple wrapping cycles. Adjustment assembly 187 may be used to
adjust the initial force by tightening or loosening spring device 183, changing the
effective length of spring device 183, preloading or unloading spring device 183,
and/or by any other suitable manner known to those skilled in the art. For example,
it is contemplated that adjustment assembly 187 may shift frame portion toward and
away from sensing element 194. Additionally or alternatively, adjustment assembly
187 may be used to twist and/or untwist spring device 183 to adjust the initial force.
Spring device 183 may include different types of springs, including, for example,
tension springs, torsion springs, elastic bands, and/or any other suitable types of
force exerting mechanisms. Spring device 183 may also include gas springs or
hydraulic devices with a piston and cylinder, with the force of such devices being
variably adjustable by adjusting fluid pressure in the devices. It is contemplated
that the force gradient may cover a small range of force values. That is, spring
device 183 may be configured such that spring device 183 acts like a long spring
such that there is a small amount of change in the force exerted by spring device
183 over the range of movement spring device 183 may undergo during a wrapping
cycle. Put another way, spring device 183 may be configured to have a low spring
rate.
[079] By increasing the initial force, a greater tension force will be required to overcome the initial force to pull sensing element 194 toward its retracted position. Moreover, once the tension force overcomes the initial force to start moving sensing element 194 toward its retracted position, even more tension force will be required to pull sensing element 194 further, since force exerting mechanism 181 may become harder to stretch once it has already undergone some stretching. Thus, the supply rate of packaging material 142 will be less than it was before increasing the initial force. The decreased supply rate will produce a decrease in the amount of film dispensed, providing a decreased payout percentage. On the other hand, by decreasing the initial force, a lesser tension force will be required to overcome the initial force to pull sensing element 194 toward its retracted position. Once the tension force overcomes the initial force to start moving sensing element 194 toward its retracted position, additional tension force will be required to pull sensing element 194 further. However, that additional tension force will be less than the tension force required to achieve a similar change in position of sensing element 194 when the initial force is greater. Thus, the supply rate of packaging material 142 will be greater than it was before decreasing the initial force. The increased supply rate will produce an increase in the amount of film dispensed, providing an increased payout percentage. However, once the selected payout percentage has been set, it may be maintained during at least a portion of the wrap cycle, even as characteristics of load 138 change, since movement of sensing element 194 may adjust the supply rate to compensate for such changes.

[080] An alternative arrangement is shown in FIGS. 10 and 11. Features shown in FIGS. 10 and 11 that are similar to features shown in FIGS. 1-3 and 7 have been assigned similar reference numerals, but with those reference numerals followed by the letter “a.” A hydrostatic transmission 200a, similar to hydrostatic transmission 200, is shown with a transmission lever 206a (transmission lever 206a is shown in multiple positions in FIGS. 10 and 11). An input/output ratio setting of hydrostatic transmission 200a may be selectively and variably adjusted by transmission lever 206a. Rotation of transmission lever 206a in a first direction may decrease the input/output ratio. Continued rotation of transmission lever 206a in the first direction may bring transmission lever 206a into a first position, where substantially all of the input at a rotatable input shaft 202a of hydrostatic transmission 200a may be transmitted or translated to a rotatable output shaft (not
shown) of hydrostatic transmission 200a. Rotation of transmission lever 206a in a second direction may increase the input/output ratio. Continued rotation of transmission lever 206a in the second direction may bring transmission lever to a second position, where transmission or translation of the input at rotatable input shaft 202a to the rotatable output shaft is prevented, putting hydrostatic drive 200a in a neutral state where rotatable input shaft 202a may rotate freely and independently of the rotatable output shaft, and the rotatable output shaft may stop rotating. Since hydrostatic transmission 200a, like hydrostatic transmission 200, operates based on fluid flow rather than based on fluid pressure, the lag time associated with operating based on fluid pressure may be avoided.

[081] Transmission lever 206a may be coupled to a sensing element 194a by linkages 197a. Sensing element 194a may include a sensing roller 195a mounted for rotation on a shaft 212a. Shaft 212a may be cantilevered, and pivotally mounted, such that one end may be capable of swinging back and forth between an extended position (generally away from hydrostatic transmission 200a) and a retracted position (generally toward hydrostatic transmission 200a). Alternatively, sensing element 194a may include a bar, one or more wheels, and/or any other suitable devices for engaging packaging material.

[082] The swinging movement of sensing element 194a may rotate transmission lever 206a through linkages 197a. As sensing element 194a swings toward its extended position, transmission lever 206a may rotate in the second direction, increasing the input/output ratio of hydrostatic transmission 200a. As sensing element 194a swings toward its retracted position, transmission lever 206a may rotate in the first direction, increasing the input/output ratio of hydrostatic transmission 200a.

[083] A force exerting mechanism 181a may affect the angular orientation of transmission lever 206a and sensing element 194a, and thus, also may affect the amount of film dispensed during the at least a portion of the revolution. Force exerting mechanism 181a may include a spring device 183a. Spring device 183a may include a compression spring having a first end 226 that engages a stop 220 on an arm 222 slidably received in a housing 224, and a second end 228 that engages housing 224, as shown in FIG. 11. Alternatively, a gas spring, a hydraulic piston and cylinder, and/or any other suitable force exerting device may be used. A first end 184a of force exerting mechanism 181a may be selectively fastened to
transmission lever 206a at any point along an arc slot 208. A second end 186a of force exerting mechanism 181a may be coupled to a frame portion 185a. Spring device 183a may exert a force causing arm 222 to extend away from housing 224. The force may be exerted by first end 184a on arc slot 208, forcing transmission lever 206a in the second direction. During normal operation, however, tension in the packaging material may exert a force on sensing element 194a drawing sensing element 194a toward its retracted position, thus forcing transmission lever 206a in the first direction. Accordingly, the force exerted by spring device 183a and the tension force exerted by the packaging material may oppose one another.

[084] The instantaneous demand and the tension force exerted by the packaging material on sensing element 194a are linked. During wrapping, changes in the tension force exerted by the packaging material on sensing element 194a may be caused by changes in instantaneous demand for the packaging material at the load. For example, an increase in the instantaneous demand produces an increase in the tension force. A decrease in the instantaneous demand produces a corresponding decrease in the tension force. Thus, sensing element 194a, by responding to changes in the tension force during wrapping, also responds to changes in the instantaneous demand. As the instantaneous demand increases (producing an increase in the tension force), sensing element 194a may be pulled toward its retracted position (e.g., toward the left in FIG. 10), causing transmission lever 206a to rotate in the first direction. As transmission lever 206a rotates in the first direction, arc slot 208 may move first end 184a of force exerting mechanism 181a toward the fixed second end 186a, thus compressing spring device 183a while increasing the supply rate of packaging material. As the instantaneous demand decreases (producing a decrease in the tension force), spring device 183a may decompress, causing first end 184a of force exerting mechanism 181a to move arc slot 208 (and transmission lever 206a) in the second direction, thus decreasing the supply rate of packaging material while moving sensing element 194a toward its extended position (e.g., toward the right in FIG. 10). This is described in more detail below.

[085] If, on the one hand, the tension force exerted on sensing element 194a by the packaging material exceeds the force exerted on sensing element 194a by spring device 183a, sensing element 194a will be pulled in the direction of the tension force (i.e., toward its retracted position). Through linkages 197a and
transmission lever 206a, movement of sensing element 194a toward its retracted position will decrease the input/output ratio of hydrostatic transmission 200a, resulting in an increase in the supply rate of packaging material. As sensing element 194a is pulled toward its retracted position, the difference between the tension force and the force exerted by spring device 183a may begin to decrease. Reasons for the decrease may include the following: movement of sensing element 194a toward its retracted position and/or the increase in the supply rate may alleviate some of the tension in the packaging material; movement of sensing element 194a toward its retracted position may compress spring device 183a, thus increasing the force spring device 183a is capable of exerting; and/or instantaneous demand may decrease as a different portion of the load is wrapped. As the difference between the tension force and the force exerted by spring device 183a begins to decrease, movement of sensing element 194a toward its retracted position will slow down. If a point is reached where the force exerted by spring device 183a once again substantially equals the tension force, sensing element 194a will stop moving toward the retracted position. The new position of sensing element 194a will correspond to a new position of transmission lever 206a and a greater supply rate of packaging material than before the increase in the tension force.

[086] If, on the other hand, the tension force falls below the force exerted by spring device 183a, spring device 183a may decompress, causing transmission lever 206a to rotate in the second direction, thus increasing the input/output ratio of hydrostatic transmission 200a, resulting in a decrease in the supply rate of packaging material. Through first end 184a, transmission lever 206a and linkages 197a, the decompression of spring device 183a may move of sensing element 194a toward its extended position. As sensing element 194a is moved toward its extended position, the difference between the tension force and the force exerted by spring device 183a may begin to decrease. Reasons for the decrease may include the following: movement of sensing element 194a toward its extended position and/or the decrease in the supply rate may increase the tension in the packaging material; decompression of spring device 183a may cause the force spring device 183a is capable of exerting to decrease; and/or instantaneous demand may increase as a different portion of the load is wrapped. As the difference between the tension force and the force exerted by spring device 183a
begins to decrease, movement of sensing element 194a toward its extended position will slow down. When a point is reached where the force exerted by spring device 183a once again substantially equals the tension force, decompression of spring device 183a will stop, as will movement sensing element 194a. The new position of transmission lever 206a and sensing element 194a will correspond to a lesser supply rate of packaging material than the position of transmission lever 206a and sensing element 194a before the decrease in the tension force.

[087] Thus, it should be apparent that because the tension force and force exerted by spring device 183a determine the position of transmission lever 206a and sensing element 194a, then the tension force and force exerted by spring device 183a also determine the supply rate of packaging material during wrapping. By controlling the supply rate of packaging material based at least in part on the tension force, and thus, the instantaneous demand for packaging material at the load, a selected payout percentage may be maintained for at least a portion of a wrap cycle, even though characteristics of the load may change. For example, when the instantaneous demand increases, the supply rate of packaging material will increase as described in the preceding sections, thus increasing the amount of dispensed packaging material. The additional amount of packaging material dispensed may compensate for the increase in instantaneous demand, keeping the payout percentage substantially constant and/or in line with the selected payout percentage. When the instantaneous demand decreases during wrapping, the decrease, the supply rate of packaging material and amount of packaging material dispensed will decrease, thus decreasing the amount of dispensed packaging material to compensate for the decrease in instantaneous demand, once again keeping the payout percentage substantially constant and/or in line with the selected payout percentage. The response of hydrostatic transmission 200a to increases and decreases in instantaneous demand, like the response of hydrostatic transmission 200, may help to avoid creating full breaks in the packaging material during wrapping.

[088] Force exerting mechanism 181a is adjustable for selectively and variably setting the force gradient exerted on transmission lever 206a by spring device 183a. Force exerting mechanism 181a may be adjusted by loosening first end 184a of force exerting mechanism 181a from transmission lever 206a, and moving first end 184a to a new position along arc slot 208. By moving first end
184a toward a lower end of arc slot 208, arm 222 is moved away from housing 224, allowing spring device 183a to decompress. By moving first end 184a toward an upper end of arc slot 208, arm 222 is moved toward housing 224, compressing spring device 183a. The force gradient exerted by spring device 183a may be greater the more spring device 183a has been pre-loaded by being compressed by arc slot 208. When first end 184a of force exerting mechanism 181a has been moved to a desired location along arc slot 208, first end 184a may be fastened to arc slot 208 by any suitable fastener, and/or by frictional force between first end 184a and arc slot 208. Markings 210 along arc slot 208 may correspond to payout percentages. That is, by fastening first end 184a of force exerting mechanism 181a next to a particular marking, a user may be setting a selected payout percentage. As described above, the selected payout percentage may be maintained for at least a portion of a wrap cycle, and/or between wrap cycles. The selected payout percentage may be decreased by loosening first end 184a and refastening first end 184a at a higher point on arc slot 208, and may be increased by loosening first end 184a and refastening first end 184a at a lower point on arc slot 208. It is contemplated that spring device 183a may have a low spring rate, like spring device 183.

[089] It is also contemplated that second end 228 of force exerting mechanism 181a may be spaced from housing 224. By providing the space, the initial movement of sensing element 194a toward its retracted position may not be countered or impeded by the force exerted by force exerting mechanism 181a. This allows sensing element 194a to rotate transmission lever 206a in the first direction, decreasing the input/output ratio of hydrostatic transmission 200a, in a shorter period of time than would be the case if the space was not provided. This may help to ensure that enough packaging material is provided at the start of a wrapping cycle to prevent ripping an initial end of the packaging material away from a clamping assembly (not shown) holding the initial end as wrapping begins. A yoke assembly 230, shown in FIG. 10, which may be spring-biased to rotate in a first direction, may engage a cam 232 that forms a part of linkages 197a, to help push sensing element 194a to its full extended position once force exerting mechanism 181a has reached full decompression/extension.

[090] According to another aspect of the present disclosure, wrapping apparatus 100 may be provided with a belted packaging material clamping and
cutting apparatus, as described in U.S. Patent Application Publication No. 2007/0204564, entitled "RING WRAPPING APPARATUS INCLUDING METERED PRE-STRETCH FILM DELIVERY ASSEMBLY," filed February 23, 2007, the entire disclosure of which is incorporated herein by reference in its entirety.

[091] According to another aspect of the present disclosure, wrapping apparatus 100 may be provided with a film drive down and roping system as disclosed in U.S. Patent Application Publication No. 2007/0209324, entitled "METHOD AND APPARATUS FOR SECURING A LOAD TO A PALLET WITH A ROPED FILM WEB," filed February 23, 2007," the entire disclosure of which is incorporated herein by reference in its entirety.

[092] According to another aspect of the disclosure, a method of using wrapping apparatus 100, shown in FIG. 1, will now be described. In operation, load 138 may be manually placed in the wrapping area, or may be conveyed into the wrapping area by a conveyor (not shown). The selected payout percentage may be set using adjustment assembly 187. A leading end of packaging material 142 may be threaded through upstream and downstream dispensing rollers 162, 164, and around any idle rollers. Then, the leading end of packaging material 142 may be wrapped around sensing element 194 before being attached to load 138 using a film clamp, by tucking the leading end of packaging material 142 into load 138, or by tying the leading end to load 138 or a portion of a pallet supporting load 138.

[093] First motor 132 may operate to rotate first drive belt 130, and thus, rotatable ring 122 and roll carriage 144, around load 138. As rotatable ring 122 rotates, a tension force may be created in the length of packaging material 142 extending between load 138 and sensing element 194. That tensile force may tend to pull sensing element 194 toward its retracted position against the force exerted on sensing element 194 by spring device 183 (see FIG. 7). Sensing element 194 will occupy a position where the tension force and the force exerted by spring device 183 are substantially equal. As roll carriage 144 rotates relative to support structure 124, second drive belt 134 may be picked up by a pulley system 250 mounted to rotatable ring 122, and may move relative to rotatable input shaft 202 of hydrostatic transmission 200, causing rotatable input shaft 202 to rotate. Rotation of input shaft 202 is immediately translated to output shaft 204 in the form of fluid flow in hydrostatic transmission 200, based on the position occupied by sensing element 194, and the rotation of the output shaft 204 in turn causes rotation of
upstream and downstream dispensing rollers 162, 164. As upstream and
downstream dispensing rollers 162, 164 rotate, they may elongate packaging
material 142 and dispense pre-stretched packaging material 142 during relative
rotation of roll carriage 144 relative to load 138. Roll carriage 144 may rotate about
a vertical axis 158 as moveable frame 118 moves up and down non-rotating frame
110 to spirally wrap packaging material 142 about load 138.

[094] During the wrapping cycle, the instantaneous demand for packaging
material 142 at load 138 may change. If the instantaneous demand increases,
producing an increase in the tension force exerted on sensing element 194,
sensing element 194 may be pulled toward its retracted position, thus increasing
the supply rate of packaging material 142 and the amount of packaging material
142 dispensed. If the instantaneous demand for packaging material 142 at load
138 decreases, producing a decrease in the tension force, sensing element 194
may be pulled toward its extended position, thus decreasing the supply rate of
packaging material 142 and the amount of packaging material 142 dispensed. In
either case, the selected payout percentage may be substantially maintained even
as the instantaneous demand changes.

[095] The instantaneous demand may both increase and decrease multiple
times or not at all during a single wrap cycle. In response to each change, if any,
the tension force acting on sensing element 194 may change. If the tension force
increases, spring device 183 may stretch, and if the tension force decreases, spring
device 183 may compress, and the position of sensing element 194 may shift
accordingly, until a new equilibrium point between the tension force and the force
exerted by spring device 183 is reached. The repositioning of sensing element 194
may correspond to a change in the supply rate of packaging material 142 to load
138 that compensates for the change in the instantaneous demand, thus
maintaining the selected payout percentage.

[096] For the embodiment shown in FIGS. 10 and 11, the method may be
similar to the above-described method, and may utilize similar components.
However, in the embodiment of FIGS. 10 and 11, the selected payout percentage
may be set by positioning first end 184a of force exerting mechanism 181a along
arc slot 208 next to the marking 210 corresponding to the selected payout
percentage.
Other embodiments of the disclosure will be apparent to those skilled in the art from consideration of the specification and practice of the disclosure disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the disclosure being indicated by the following claims.
WHAT IS CLAIMED IS:

1. An apparatus for wrapping a load with packaging material, comprising:
   - a packaging material dispenser for dispensing packaging material;
   - a relative rotation assembly for providing relative rotation between the load and the packaging material dispenser;
   - a mechanical connection operatively coupling the packaging material dispenser to the relative rotation assembly, wherein the relative rotation assembly is configured to drive the packaging material dispenser through the mechanical connection;
   - a force exerting mechanism operatively coupled to the mechanical connection; and
   - a sensing element configured to sense a characteristic of dispensed packaging material, the sensing element being operatively coupled to the mechanical connection;
   - wherein the force exerting mechanism and the sensing element are configured to control the mechanical connection to maintain a selected ratio of packaging material dispensed to demand for packaging material at the load for at least a portion of a wrap cycle.

2. The apparatus of claim 1, wherein the force exerting mechanism and the sensing element are configured to maintain the ratio of packaging material dispensed to demand at a level sufficient to produce a desired wrap force on the load.

3. The apparatus of claim 1, wherein the force exerting mechanism and the sensing element are configured to maintain the ratio of packaging material dispensed to demand at a level sufficient to produce a desired containment force on the load.

4. The apparatus of claim 1, wherein the force exerting mechanism and the sensing element are configured to maintain the ratio of packaging material dispensed to demand at a level sufficient to meet the containment needs of the load.
5. The apparatus of claim 1, wherein the force exerting mechanism and the sensing element are configured to maintain the ratio of packaging material dispensed to demand within a range of values sufficient to maintain at least one of a wrap force and a containment force exerted on the load in a range sufficient to meet containment needs of the load.

6. The apparatus of claim 1, wherein the force exerting mechanism includes a spring member configured to exert a force on the mechanical connection.

7. The apparatus of claim 6, wherein the force exerting mechanism includes a compression spring.

8. The apparatus of claim 6, wherein the sensing element is configured to exert a force on the mechanical connection based at least in part on the sensed characteristic.

9. The apparatus of claim 8, wherein the force exerted by the force exerting mechanism and the force exerted by the sensing element oppose one another.

10. The apparatus of claim 9, wherein the mechanical connection includes an input and an output.

11. The apparatus of claim 10, wherein the mechanical connection is configured such that connectivity between the input and the output increases when the force exerted by the sensing element overcomes the force exerted by the force exerting mechanism.

12. The apparatus of claim 10, wherein the mechanical connection is configured such that connectivity between the input and the output decreases when the force exerted by the force exerting mechanism overcomes the force exerted by the sensing element.
13. An apparatus for wrapping a load with packaging material, comprising:
   a packaging material dispenser for dispensing packaging material;
   a relative rotation assembly for providing relative rotation between the load and the packaging material dispenser;
   a mechanical connection operatively coupling the packaging material dispenser to the relative rotation assembly, wherein the relative rotation assembly is configured to drive the packaging material dispenser through the mechanical connection; and
   a sensing element configured to sense a change in demand for packaging material at the load and adjust the mechanical connection in response to the change in demand to maintain a ratio of packaging material dispensed to demand in a selected range for at least a portion of a wrap cycle.

14. The apparatus of claim 13, wherein the sensing element is configured to engage a portion of the packaging material extending between the packaging material dispenser and the load to sense the change in demand.

15. The apparatus of claim 13, wherein the demand is an instantaneous demand.

16. The apparatus of claim 13, wherein the sensing element is configured to respond to the change in packaging material demand by moving from a first position to a second position.

17. The apparatus of claim 16, wherein the sensing element includes a shaft including a hinged fixed end and a free end, the shaft being configured to swing about the hinged fixed end between the first position and the second position.

18. The apparatus of claim 17, further including a force exerting mechanism coupled to the shaft, the force exerting mechanism being configured to exert a force on the shaft.
19. The apparatus of claim 18, wherein the force exerting mechanism is configured to maintain the ratio of packaging material dispensed to demand substantially constant as demand changes by controlling positioning of the sensing element with the force exerted by the force exerting mechanism.

20. The apparatus of claim 18, wherein a first portion of the force exerting mechanism is coupled to the shaft.

21. The apparatus of claim 20, wherein a second portion of the force exerting mechanism is coupled to a frame portion of the packaging material dispenser.

22. The apparatus of claim 17, further including a force exerting mechanism coupled to the mechanical connection, the force exerting mechanism being configured to exert a force on the mechanical connection.

23. The apparatus of claim 22, wherein the force exerting mechanism includes an arm slidably received in a housing.

24. The apparatus of claim 23, wherein the force exerting mechanism includes a spring engaging the arm and the housing, the spring being configured to bias the arm to an extended position relative to the housing.

25. The apparatus of claim 23, wherein the arm is coupled to the mechanical connection, and the housing is coupled to a frame portion of the packaging material dispenser.

26. The apparatus of claim 25, wherein the arm is selectively fastened along a slot in the mechanical connection.

27. The apparatus of claim 26, wherein moving the arm along the slot in a first direction increases the force exerted on the mechanical connection by the force exerting mechanism.
28. The apparatus of claim 27, wherein moving the arm along the slot in a second direction decreases the force exerted on the mechanical connection by the force exerting mechanism.

29. The apparatus of claim 13, wherein the mechanical connection includes a mechanical input/output ratio control operatively coupling the relative rotation assembly to the packaging material dispenser.

30. The apparatus of claim 29, wherein the mechanical input/output ratio control includes a hydrostatic transmission.

31. The apparatus of claim 29, wherein an input of the mechanical input/output ratio control is operatively coupled to the relative rotation assembly.

32. The apparatus of claim 31, wherein an output of the mechanical input/output ratio control is operatively coupled to the packaging material dispenser.

33. The apparatus of claim 32, wherein connectivity between the input and the output of the mechanical input/output ratio control is determined at least in part by positioning of the sensing element.

34. The apparatus of claim 33, wherein movement of the sensing element in a first direction increases connectivity between the input and output of the mechanical input/output ratio.

35. The apparatus of claim 34, wherein movement of the sensing element in a second direction decreases connectivity between the input and output of the mechanical input/output ratio.

36. The apparatus of claim 34, wherein movement of the sensing element in a second direction is indicative of a decrease in connectivity between the input and output of the mechanical input/output ratio.
37. A method for wrapping a load with packaging material, the method comprising:

- providing relative rotation between a packaging material dispenser and the load with a relative rotation assembly;
- driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection operatively coupling the packaging material dispenser and the relative rotation assembly;
- engaging a portion of the packaging material extending between the packaging material dispenser and the load with a sensing element, wherein a change of position of the sensing element is indicative of a change in demand for packaging material at the load; and
- adjusting the mechanical connection based at least in part on movement of the sensing element to maintain a ratio of packaging material dispensed to demand in a selected range for at least a portion of a wrap cycle.

38. The method of claim 37, wherein movement of the sensing element is indicative of a change in load girth between a first portion of the load and a second portion of the load.

39. The method of claim 37, wherein movement of the sensing element is indicative of a change in the shape of a portion of the load being wrapped.

40. The method of claim 37, wherein driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection includes driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical input/output ratio control.

41. The method of claim 40, wherein adjusting the mechanical connection operatively coupling the packaging material dispenser and the relative rotation assembly includes adjusting power transmission in the mechanical input/output ratio control.
42. The method of claim 40, wherein adjusting power transmission in the mechanical input/output ratio control includes adjusting connectivity between an input of the mechanical input/output ratio control and an output of the mechanical input/output ratio control.

43. The method of claim 37, further including controlling movement of the sensing element with an adjustable force exerting mechanism to maintain the ratio of packaging material dispensed to demand.

44. A method for wrapping a load with packaging material, the method comprising:
   providing relative rotation between a packaging material dispenser and the load with a relative rotation assembly;
   driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection operatively coupling the packaging material dispenser and the relative rotation assembly; and
   controlling the mechanical connection with a sensing element operatively coupled to the mechanical connection;
   engaging a portion of the packaging material extending between the packaging material dispenser and the load with the sensing element to monitor tension of the packaging material; and
   moving the sensing element to control the mechanical connection to maintain an amount of packaging material dispensed relative to the demand for packaging material at the load in a selected range for at least a portion of a wrapping cycle.

45. The method of claim 44, wherein maintaining an amount of packaging material dispensed relative to the demand for packaging material at the load substantially constant includes maintaining the amount dispensed relative to the demand substantially constant as tension of the packaging material varies.

46. The method of claim 44, wherein tension in the packaging material changes due to a change in load girth.
47. The method of claim 44, wherein tension in the packaging material changes due to a change in a shape of the load.

48. The method of claim 44, wherein driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection includes driving the packaging material dispenser with the relative rotation assembly through a mechanical input/output ratio control.

49. The method of claim 48, wherein moving the sensing element includes pivoting the sensing element about a hinged fixed end.

50. The method of claim 49, wherein pivoting the sensing element adjusts the mechanical input/output ratio control.

51. The method of claim 44, further including controlling movement of the sensing element with an adjustable force exerting mechanism.

52. The method of claim 44, wherein maintaining an amount of packaging material dispensed relative to demand in a selected range includes maintaining the amount of packaging material dispensed relative to the demand substantially constant for at least a portion of the wrapping cycle.

53. A method for wrapping a load with packaging material, the method comprising:
   - providing relative rotation between a packaging material dispenser and the load with a relative rotation assembly;
   - driving the packaging material dispenser to dispense packaging material with the relative rotation assembly through a mechanical connection operatively coupling the packaging material dispenser and the relative rotation assembly;
   - engaging a portion of the packaging material extending between the dispensing assembly and the load with a sensing element operatively coupled to a control element of the mechanical connection;
   - exerting a force on the control element with an adjustable force exerting mechanism; and
controlling the mechanical connection with the control element, through positioning of the sensing element and force exerted by the adjustable force exerting mechanism, to maintain a ratio of packaging material dispensed relative to demand for packaging material at the load substantially constant for at least a portion of a wrap cycle.

54. The method of claim 53, wherein exerting a force on the control element includes exerting the force on the control element with a spring device.

55. The method of claim 54, wherein exerting the force on the control element with a spring device includes adjusting the force exerted on the control element by adjusting the spring device.

56. The method of claim 55, wherein adjusting the spring device includes adjusting a length of the spring device.

57. The method of claim 53, wherein driving the packaging material dispenser with the relative rotation assembly through a mechanical connection includes driving the packaging material dispenser with the relative rotation assembly through a mechanical input/output ratio control operatively coupling the relative rotation assembly to the packaging material dispenser.

58. The method of claim 57, wherein controlling the mechanical connection with the control element includes adjusting connectivity between the input and output of the mechanical input/output ratio control.

59. The method of claim 57, wherein driving the packaging material dispenser with the relative rotation assembly through a mechanical input/output ratio control includes driving the packaging material dispenser with the relative rotation assembly through a hydrostatic transmission.

60. The method of claim 59, wherein controlling the mechanical connection with the control element includes adjusting a valve assembly in the hydrostatic transmission.
61. An apparatus for stretch wrapping a load, comprising:
   a packaging material dispenser for dispensing packaging material, the
   packaging material dispenser including a dispensing assembly for pre-stretching
   the packaging material;
   a relative rotation assembly for providing relative rotation between the load
   and the packaging material dispenser;
   a mechanical connection operatively coupling the dispensing assembly to
   the relative rotation assembly, wherein the relative rotation assembly is configured
   to drive the dispensing assembly through the mechanical connection;
   a sensing roller configured to sense a change in demand for packaging
   material at the load, and to move to adjust the mechanical connection in response
   to the change in packaging material demand; and
   an adjustable force exerting mechanism operatively coupled to the sensing
   roller, the adjustable force exerting mechanism being configured to control
   movement of the sensing roller.

62. An apparatus for wrapping a load with packaging material,
   comprising:
   a packaging material dispenser for dispensing packaging material;
   a relative rotation assembly for providing relative rotation between the load and the
   packaging material dispenser;
   a mechanical connection operatively coupling the packaging material
dispenser to the relative rotation assembly, wherein the relative rotation assembly
is configured to drive the packaging material dispenser through the mechanical
connection;
   a force exerting mechanism operatively coupled to the mechanical
connection; and
   a sensing element configured sense a characteristic of dispensed packaging
material, the sensing element being operatively coupled to the mechanical
connection;
   wherein the force exerting mechanism and the sensing element are
configured to control the mechanical connection to maintain a wrap force exerted
by the dispensed packaging material on the load in a selected force range for at least a portion of a wrap cycle.

63. The apparatus of claim 62, wherein the force exerting mechanism and the sensing element are configured to maintain the wrap force in the selected force range by maintaining a ratio of packaging material dispensed to demand for packaging material at the load in a selected ratio range.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

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**ADD.**

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

**B. FIELDS SEARCHED**

- Minimum documentation searched (classification system followed by classification symbols)
  - B65B

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

Electronic database consulted during the international search (name of database and, where practical, search terms used)

- EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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| Column 10, line 8 - line 31; figures 2-6,9 | |
| Column 11, line 27 - column 12, line 58 | |

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Further documents are listed in the continuation of Box C. See patent family annex.

- * Special categories of cited documents:
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Date of the actual completion of the international search: 19 May 2011

Date of mailing of the international search report: 31/05/2011

Name and mailing address of the ISA:
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Fax: (+31-70) 340-3016

Authorized officer:
Johne, Olaf

Form PCT/ISA/210 (second sheet) (April 2005)
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