

MULTIPLE TAPE REEL HANDLING APPARATUS

Technical Field

The present disclosure relates to a tape reel handling apparatus for a tape and reel machine
5 configured for loading flexible tape onto and/or unloading flexible tape from multiple tape
reels, where the flexible tape carries components such as semiconductor devices. A tape reel
handling apparatus configured for carrying multiple tape reels can concurrently displace the
tape reels relative to a common tape input / output axis such that each tape reel alternately
10 resides at (a) a feeding position at which it can be loaded or unloaded by the tape and reel
machine, or (b) a standby position at which it can be removed from the tape reel handling
apparatus and replaced with another tape reel while flexible tape is being loaded onto or
unloaded from the tape reel disposed at the feeding position.

Background

15 Tape and reel machines transfer components such as semiconductor devices (e.g.,
semiconductor die or packaged integrated circuit chips) onto a flexible linear tape, and
concurrently feed the flexible linear tape to a tape reel while the reel is spun. As a result, the
flexible linear tape is progressively circumferentially wound around the tape reel. This
provides an efficient manner of storing the flexible linear tape and the components carried
20 thereby. Once a tape reel that is receiving the flexible linear tape is fully loaded with a given
length of the flexible linear tape, this full reel must be replaced with an empty reel, such that
additional components can continue to be transferred to the flexible linear tape, and the
flexible linear tape can continue to be fed to, wound around, and stored on this replacement
tape reel. That is, the full reel must be changed or swapped out for an empty reel.

25 Manual tape reel changing involves removing a first full tape reel from the tape and reel
system, and manually replacing this first full tape reel with a second empty tape reel. During
manual tape reel changing, the tape and reel machine cannot continue to operate until after
the first full tape reel has been manually removed, and the second empty tape reel has been
30 manually mounted in position where the first full tape reel formerly resided. Thus, from the
time at which the first tape reel becomes full until after (a) the first tape reel has been
manually removed, and (b) the second tape reel has been manually mounted in position, the

tape and reel machine is not operating, resulting in tape and reel machine interruption or downtime, adversely affecting throughput.

Automated systems or apparatuses for automatically changing tape reels (e.g., as described in
5 US Patent Publication No. 2011/0220755 and US Patent Publication No. 2003/0046808)
exist, which can increase throughput. However, existing automated tape reel changing
systems or apparatuses are undesirably complex from a mechanical standpoint, and can be
correspondingly costly. Additionally, some automated tape reel changing systems can
10 increase the overall spatial footprint of a tape and reel system significantly beyond that of a
conventional manual tape and reel system. A need exists for a mechanically simple, low
cost, throughput efficient, and space efficient apparatus for a tape and reel machine, by which
multiple tape reels can be automatically managed.

Summary

15 In accordance with an aspect of the present disclosure, a process is provided for handling a
plurality of tape reels using a multi-reel handling apparatus configured for operation with a
tape and reel machine. The tape and reel machine is configured for displacing a flexible tape
carrying components along a tape transport axis to transfer the tape and the components
carried thereby between the tape and reel machine and a tape reel disposed at a feeding
20 position common to the plurality of tape reels. The process includes: disposing a first tape
reel having a first winding axis at the feeding position; disposing a second tape reel having a
second winding axis at a first standby position within a set of standby positions, wherein each
standby position is offset from the tape transport axis (and hence also offset from the feeding
position); spinning the first tape reel about the first winding axis while transferring the tape
25 between the tape and reel machine and the first tape reel; automatically determining whether
transfer of the tape between the tape and reel machine and the first tape reel is complete; and
performing a set of tape reel swap operations after transfer of the tape between the tape and
reel machine and the first tape reel is complete, the set of tape reel swap operations including
simultaneously displacing the first and second tape reels by (a) linearly shuttling the first and
30 second tape reels in a common direction perpendicular to the tape transport axis, or (b)
changing the physical locations of the first and second tape reels by rotating the first and
second tape reels about a common pivot axis that is perpendicular to the first and second
winding axes to thereby (i) dispose the second tape reel at the feeding position, and (ii)

dispose the first tape reel at a second standby position within the set of standby positions. The pivot axis is parallel or perpendicular to the tape transport axis.

5 The first and second winding axes can be coincident with each other when the second tape reel is disposed at the feeding position. The first standby position and the second standby position can include or be the same physical location or different physical locations in space.

10 Simultaneously displacing the first and second tape reels can include activating a tape reel shuttle / swap actuator to linearly or rotationally displace a support structure that carries the first and second tape reels. Simultaneously linearly shuttling the first and second tape reels includes horizontally shuttling the first and second tape reels in a direction parallel to at least one of the first and second winding axes. In association with such shuttling, the first standby position and the second standby position can be on opposite sides of the tape transport axis. Changing the physical locations of the first and second tape reels by simultaneously rotating
15 the first and second tape reels about the pivot axis includes rotating the first and second tape reels such that the first and second winding axes circumferentially travel in an arc around the pivot axis within a plane that is perpendicular to the pivot axis. In association with such rotation about the pivot axis, the first standby position and the second standby positions can be on the same side of the tape transport axis.

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The process can further include spinning the second tape reel about the second winding axis; and automatically initiating transfer of the tape between the tape and reel machine and the second tape reel while the first tape reel is disposed at the second standby position. The process can also include removing the first tape reel from the multi-reel handling apparatus
25 and replacing it with a third tape reel while the second tape reel is disposed at the feeding position and the tape is being transferred between the tape and reel machine and the second tape reel. Removing the first tape reel from the multi-reel handling apparatus and replacing it with the third tape reel occurs without delaying or interrupting the transfer of the tape between the tape and reel machine and the second tape reel. The process can include
30 removing a plurality of tape reels from the multi-reel handling apparatus and replacing each of the plurality of removed tape reels with another tape reel on the multi-reel handling apparatus while the second tape reel is disposed at the feeding position and the tape is being transferred between the tape and reel machine and the second tape reel.

The process can include spinning the first tape reel about the first winding axis using a first winding actuator when the first tape reel is disposed at the feeding position, and spinning the second tape reel about the second winding axis using a second winding actuator distinct from
5 the first winding actuator when the second tape reel is disposed at the feeding position.

The plurality of tape reels can include a first plurality of tape reels including the first and second tape reels, and a second plurality of tape reels including a third tape reel and a fourth tape reel respectively having a third winding axis and a fourth winding axis. The process can
10 correspondingly further include: simultaneously linearly shuttling the first through fourth tape reels in a common direction perpendicular to the tape transport axis to thereby simultaneously (iii) dispose the first and second tape reels in an unloading zone in which at least one of the first and second tape reels is removable from the multi-reel handling apparatus, and (iv) dispose the third tape reel at the feeding position while disposing the
15 fourth tape reel at a standby position within the set of standby positions; and simultaneously displacing the third and fourth tape reels relative to the feeding position while the first and second tape reels remain in the unloading zone by (a) linearly shuttling the first through fourth tape reels in a common direction perpendicular to the tape transport axis, or (b) changing the physical locations of the third and fourth tape reels by rotating the third and
20 fourth tape reels about a common pivot axis that is perpendicular to the third and fourth winding axes to thereby (i) dispose the fourth tape reel at the feeding position, and (ii) dispose the third tape reel at a standby position within the set of standby positions.

The process can also include removing each of the first tape reel and the second tape reel
25 from the multi-reel handling apparatus and replacing the first tape reel with a fifth tape reel and the second tape reel with a sixth tape reel without delaying or interrupting the transfer of the tape between the tape and reel machine and at least one of the third tape reel and the fourth tape reel.

30 The plurality of tape reels can also include a third plurality of tape reels including a fifth tape reel and a sixth tape reel respectively having a fifth winding axis and a sixth winding axis. The set of tape reel swap operations can further include: simultaneously linearly shuttling the first through sixth tape reels in a common direction perpendicular to the tape transport axis to

thereby simultaneously (iii) dispose the first through fourth tape reels in the unloading zone at which at least one of the first through fourth tape reels is removable from the multi-reel handling apparatus, and (iv) dispose the fifth tape reel at the feeding position while disposing the sixth tape reel at a standby position within the set of standby positions; and
5 simultaneously displacing the fifth and sixth tape reels relative to the feeding position while the first through fourth tape reels remain in the unloading zone by (a) linearly shuttling the first through sixth tape reels in a common direction perpendicular to the tape transport axis, or (b) changing the physical locations of the fifth and sixth tape reels by rotating the fifth and sixth tape reels about a common pivot axis that is perpendicular to the fifth and sixth winding
10 axes to thereby (i) dispose the sixth tape reel at the feeding position, and (ii) dispose the fifth tape reel at a standby position within the set of standby positions.

In accordance with an aspect of the present disclosure, a multi-reel handling apparatus is configured for collectively displacing a plurality of tape reels relative to a common feeding
15 position of a tape and reel machine at which a flexible tape carrying components is displaceable along a tape transport axis for transfer between the tape and reel machine and one of the plurality of tape reels that is disposed at the feeding position. The apparatus can include: a set of tape reel support structures, each tape reel support structure configured for carrying a plurality of tape reels and providing a plurality of tape reel holding mechanisms,
20 each of the plurality of tape reel holding mechanisms including a shaft configured for carrying a tape reel such that the tape reel is spinnable about a winding axis parallel to the shaft; a set of multi-reel displacement actuators (e.g., one or more linear displacement based shuttle actuators and/or one or more rotation based swap actuators) including: (a) an actuator configured for linearly shuttling each tape reel support structure and the tape reel holding
25 mechanisms carried thereby in a direction perpendicular to the tape transport axis, and/or (b) an actuator configured for changing the physical locations of the tape reel holding mechanisms carried by a selected tape reel support structure by rotating the selected tape reel support structure about a pivot axis that is perpendicular to the shaft of each of the tape reel holding mechanisms carried thereby, wherein the set of multi-reel displacement actuators is
30 configured for selectively (i) disposing a particular tape reel holding mechanism of the plurality of tape reel holding mechanisms and the shaft thereof in alignment with the feeding position such that the shaft extends through a plane containing the tape transport axis and can carry a tape reel to or from which the tape can be automatically transferred, and (ii) disposing

each other tape reel holding mechanism of the plurality of tape reel holding mechanisms out of alignment with the feeding position at a standby position within a set of standby positions corresponding to the feeding position or in an unloading zone; and a set of winding actuators configured for selectively spinning the shaft of a tape reel holding mechanism when the tape reel holding mechanism is disposed in alignment with the feeding position. The pivot axis is parallel or perpendicular to the tape transport axis.

The plurality of tape reel holding mechanisms includes a first tape reel holding mechanism having a first shaft and a second tape reel holding mechanism having a second shaft. The first and second shafts can be parallel to each other when the first tape reel holding mechanism or the second tape reel holding mechanism is in alignment with the feeding position.

The set of multi-reel displacement actuators can be configured for concurrently linearly shuttling at least two tape reel support structures in a direction parallel to at least a first shaft of a first tape reel holding mechanism and a second shaft of a tape reel holding mechanism carried by each of the at least two tape reel support structures. In such a configuration, the set of multi-reel displacement actuators can be configured for disposing (a) a first shaft of a first tape reel holding mechanism in alignment with the feeding position while a second shaft of the first tape reel holding mechanism is disposed on a first side of the tape transport axis, and (b) the second shaft of the first tape reel holding mechanism in alignment with the feeding position while the first shaft of the first tape reel holding mechanism is disposed on a second side of the tape transport axis opposite to the first side of the tape transport axis.

The set of multi-reel displacement actuators can alternatively be configured for disposing (a) a first shaft of a first tape reel holding mechanism in alignment with the feeding position while a second shaft of the first tape reel holding mechanism is disposed on a first side of the tape transport axis, and (b) the second shaft of the first tape reel holding mechanism in alignment with the feeding position while the first shaft of the first tape reel holding mechanism is disposed on the first side of the tape transport axis.

The set of multi-reel displacement actuators can further be configured for disposing a second tape reel support structure and a plurality of tape reel holding mechanisms carried thereby in

the unloading zone while the first shaft or the second shaft carried by the first tape reel holding structure is disposed in alignment with the feeding position.

The set of multi-reel displacement actuators can be configured for disposing a second tape reel support structure and the plurality of tape reel holding mechanisms carried thereby on a first side of the tape transport axis and disposing a third tape reel support structure and a plurality of tape reel holding mechanisms carried thereby on a second side of the tape transport axis opposite to the first side of the tape transport axis while the first shaft or the second shaft carried by the first tape reel holding structure is disposed in alignment with the feeding position.

The set of multi-reel displacement actuators can be configured for collective precise linear shuttling of each of a plurality of tape reel support structures in a direction perpendicular to the tape transport axis toward, to, and past the feeding position to selectively sequentially dispose the shaft of each tape reel holding mechanism of each of the plurality of tape reel support structures in alignment with the feeding position. Alternatively, the set of multi-reel displacement actuators can be configured for (a) collective precise linear shuttling of each of a plurality of tape reel support structures in a direction perpendicular to the tape transport axis toward, to, and past the feeding position to selectively dispose the shaft of a first tape reel holding mechanism of each of the plurality of tape reel support structures in alignment with the feeding position, and (b) for each tape reel support structure, collective precise rotation of the tape reel support structure about a pivot axis corresponding thereto when a shaft carried by the tape reel support structure is disposed in alignment with the feeding position.

The set of winding actuators can include a first spin actuator and a distinct second spin actuator corresponding to each tape reel support structure, wherein the first and second spin actuators corresponding to a given tape reel support structure are respectively configured for spinning a first shaft and a second shaft carried by the tape reel support structure.

Brief Description of the Drawings

FIG. 1A is a schematic illustration showing a perspective view of a representative dual-reel handling apparatus for a tape and reel machine in accordance with an embodiment of the present disclosure.

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FIG. 1B is a schematic illustration showing a top view of the dual-reel handling apparatus of FIG. 1, and FIG. 1C is a schematic illustration showing a plan view of the dual-reel handling apparatus of FIG. 1.

10 FIG. 2 is a schematic illustration showing a frontal view of portions of a dual-reel handling apparatus, indicating representative dual tape reel rotation about a pivot axis ρ during tape reel flip operations in accordance with an embodiment of the present disclosure.

15 FIG. 3A is a schematic illustration of a full tape reel positioned at a tape reel feeding position and an empty tape reel positioned at a standby position following completion of flexible tape transfer operations directed to the tape reel positioned at the feeding position in accordance with an embodiment of the present disclosure.

20 FIG. 3B is a schematic illustration of the full tape reel shown in FIG. 3A positioned at the standby position and the empty tape reel shown in FIG. 3A positioned at the feeding position as a result of a set of tape reel rotation or flip operations in accordance with an embodiment of the present disclosure.

25 FIGs. 4A – 4E are schematic illustration showing portions of a rotatable multi-reel handling apparatus from a frontal view along a tape reel pivot axis ρ , and representative tape reel location transitions that occur as a result of tape reel rotation operations performed by the rotatable multi-reel handling apparatus in accordance with an embodiment of the present disclosure.

30 FIG. 5A – 5E are schematic illustrations of a rotatable dual-reel handling apparatus and representative tape reel location transitions performed thereby in accordance with another embodiment of the present disclosure.

FIG. 6A – 6F are schematic illustrations of a dual-reel shuttling apparatus configured for displacing two tape reels in either direction along a tape reel shuttle axis σ , and representative tape reel location transitions performed thereby in accordance with an embodiment of the present disclosure.

FIGs. 7A – 7B are schematic illustrations of multi-reel rotation and shuttling apparatuses in accordance with additional embodiments of the present disclosure.

FIGs. 8A – 8B are schematic illustrations of multi-reel rotation and shuttling apparatuses in accordance with still further embodiments of the present disclosure.

FIGs. 9A – 9B are schematic illustrations of multi-reel shuttling apparatuses in accordance with particular embodiments of the present disclosure.

FIGs. 10 is a schematic illustration of a multi-reel rotation apparatus in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

In the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular FIG. or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another FIG. and/or descriptive material associated therewith. The use of “/” in a FIG. or associated text is understood to mean “and/or” unless otherwise indicated. The use of the term(s) “approximately” or “about” is understood to indicated or mean within a tolerance or range (e.g., +/- 20%, +/-15%, +/-10%, +/-5%, or +/-0%). Similarly, the recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range (e.g., to within +/- 20%, +/-15%, +/-10%, +/-5%, or +/-0%).

As used herein, the term “set” corresponds to or is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least 1 (i.e., a set as defined herein

can correspond to a unit, singlet, or single element set, or a multiple element set), in accordance with known mathematical definitions (for instance, in a manner corresponding to that described in *An Introduction to Mathematical Reasoning: Numbers, Sets, and Functions*, “Chapter 11: Properties of Finite Sets” (e.g., as indicated on p. 140), by Peter J. Eccles, Cambridge University Press (1998)). In general, an element of a set can include or be a system, an apparatus, a device, a structure, an object, a process, a physical parameter, or a value depending upon the type of set under consideration.

Overview

As individuals having ordinary skill in the relevant art will readily understand, a tape and reel machine is configured for transferring components such as semiconductor devices (e.g., packaged semiconductor chips) to and/or from a flexible tape, which herein can be referred to as a “flexible linear tape,” “flexible tape” or “tape.” The tape and reel machine is additionally configured for feeding the tape along a direction that defines a tape transport or tape input / output axis, toward and onto an initially empty reel or tape reel located at a feeding position aligned with the tape input / output axis as the tape reel is spun in a loading direction about a winding axis. As a result, the tape is wound or coiled about and thus loaded onto the tape reel for purpose of efficiently storing the components carried by the tape on the tape reel. The tape and reel machine can further be configured for receiving tape from an initially full tape reel located at the feeding position as the tape reel is spun in an unloading direction about the winding axis, thereby removing tape from the tape reel, such that the tape and reel machine can remove or “de-tape” components from the tape (e.g., in a reverse sense relative to tape reel loading), in a manner also readily understood by those having ordinary skill in the relevant art. An individual having ordinary skill in the relevant art will further understand that the tape and reel machine is configured for indexed displacement of the tape along the tape input / output axis, toward or away from a tape reel disposed at the feeding position.

The tape input / output axis corresponds or is parallel to or extends along an axis along which the tape is output from or input to the tape and reel machine; or correspondingly, an axis along which the tape is input to or output from a tape reel disposed at the feeding position. The tape input / output axis can correspond to or be defined by a path along or channel within which portions of the flexible tape travel on or away from / toward the tape and reel machine

during tape loading / unloading operations involving a tape reel disposed at the feeding position. Correspondingly, during tape loading or unloading operations, portions of the tape respectively traveling toward or away from the tape reel disposed at the feeding position travel along the tape input / output axis. The tape input / output axis can correspond to or be defined by a physical structure such as a tape track and/or guide carried by tape and reel machine, along or within which tape displacement occurs during tape reel loading or unloading operations. Additionally, the tape input / output axis can be defined as extending through the feeding position, at which tape loading or unloading operations for the tape reel disposed thereat can occur.

Embodiments in accordance with the present disclosure involve or include a tape reel handling apparatus for a tape and reel machine, where the tape reel handling apparatus is configured or configurable for carrying / handling and positionally displacing multiple tape reels at the same time. Such a tape reel handling apparatus can be referred to as a multi-reel handling apparatus. In various embodiments, the multi-reel handling apparatus is configured for collectively displacing a plurality of tape reels that share (e.g., time-share and position share, in a sequenced or alternating manner) a common or the same feeding position or tape input / output axis aligned with the feeding position, such that (a) one tape reel of the plurality of tape reels is precisely positionally displaced or shifted to reside at the feeding position, whereat transfer of the flexible tape between the tape and reel machine and this tape reel can occur, while (b) each other tape reel of the plurality of tape reels is displaced or positionally shifted to reside away from the feeding position out of alignment with the tape input / output axis at a particular standby position, whereat the transfer of the flexible tape between the tape and reel machine and the other tape reel(s) does not occur. The standby position is offset (e.g., vertically, laterally, and/or rotationally / pivotally offset) from the feeding position and the tape input / output axis. At least one standby position corresponds to a spatial location at which a tape reel can be removed or dismounted from the multi-reel handling apparatus (e.g., by a human operator and/or an automated / robotic operator, worker, or work unit), following which a replacement tape reel can be mounted to the multi-reel handling apparatus (e.g., by the operator), while flexible tape transfer operations directed to the tape reel disposed at the feeding position are automatically initiated or are currently in progress / underway.

After flexible tape transfer operations directed to the tape reel currently located at the feeding position are complete (e.g., when flexible tape loading onto the tape reel located at the feeding position is complete), the multi-reel handling apparatus automatically precisely displaces the plurality of tape reels to thereby transfer, displace, or shift the tape reel currently located at the feeding position away from the feeding position, toward and to a predetermined standby position, while simultaneously precisely transferring, displacing, or shifting a tape reel at a given standby position (e.g., an empty tape reel) toward and to the feeding position. As a result, each tape reel of the plurality of tape reels is displaced or travels along a predictable or predetermined travel path relative to the feeding position, such that for any given tape reel mounted to the multi-reel handling apparatus, the tape reel is located at the feeding position during flexible tape transfer operations directed to this tape reel, and is located away from the feeding position at one or more standby positions during flexible tape transfer operations directed to another tape reel disposed at the feeding position. Thus, the multi-reel handling apparatus automatically switches, exchanges, alternates, or swaps the positions of individual tape reels relative to the feeding position and the standby position(s) over time. The collective displacement of the plurality of tape reels relative to the tape input / output axis or the feeding position can occur automatically or semi-automatically on a selective / selectable / programmable basis (e.g., in accordance with a set of program instructions executable by a processing unit).

With respect to tape reel loading operations, when an initially empty first tape reel disposed at the feeding position has been loaded with tape and is thus full, it can be automatically displaced away from the feeding position without unnecessary delay (e.g., essentially or nearly immediately), toward and to a standby position (e.g., a predetermined, programmably defined, or selectable standby position), simultaneous with the displacement of an empty second or next tape reel toward and to the feeding position. Once the second tape reel arrives at the feeding position, it can be automatically loaded with tape without further delay, thus reducing unnecessary interruption of tape reel loading operations performed on consecutive tape reels by the tape and reel machine, thereby consistently maintaining or significantly enhancing tape reel loading throughput. While the second tape reel is positioned at the feeding position and is being loaded with tape, the full first tape reel disposed at the standby position can be removed or dismounted from the multi-tape reel handling apparatus, and

replaced with another empty tape reel (e.g., by way of operator mounting of a third tape reel to multi-tape reel handling apparatus, after removal of the full first tape reel therefrom).

Because the multi-tape reel handling apparatus automatically and efficiently transfers a next-to-be-loaded empty tape reel from a standby position to the feeding position simultaneous
5 with the transfer of the most-recently filled or full tape reel from the feeding position to a standby position, and can automatically initiate and perform tape transfer operations directed to the empty tape reel disposed at the feeding position, the multi-tape reel handling apparatus reduces or minimizes operator time requirements or time pressure conventionally associated
10 with the need for quickly removing a filled or full tape reel from the feeding position to avoid throughput reduction. As a result, an operator has significantly more time available for swapping out tape reels because one tape reel (e.g., of a tape reel pair) is disposed at the standby position while another tape reel (e.g., of the tape reel pair) is concurrently being loaded at the feeding position, and tape reel loading is typically expected to require
15 significantly more time than removal of a tape reel from and mounting of a replacement tape reel to the multi-reel handling apparatus. Consequently, by way of a multi-reel handling apparatus configured to perform tape reel exchange / swap operations involving the collective displacement of a plurality of tape reels relative to a common tape input / output axis or feeding position, a sequence or stream of successive tape reels that share the common tape
20 input / output axis or feeding position can be consecutively loaded with tape and removed from the multi-reel handling apparatus with significantly more consistent / predictable and/or enhanced throughput, and/or without delaying or interrupting the transfer of tape to or from a given tape reel once that tape reel is disposed at the feeding position.

Moreover, by way of a multi-reel handling apparatus in accordance with an embodiment of
25 the present disclosure, a single operator can correspondingly successfully manage a greater number of tape and reel machines (e.g., by a factor of approximately 100% - 500%) compared to the prior art, such that an overall tape reel loading throughput associated with a plurality of tape and reel machines can be significantly more consistent / predictable and/or
30 increased, and tape and reel machine interruptions or downtime due to tape reel changes / swap-outs can correspondingly be significantly reduced or effectively eliminated.

Analogous considerations to those described above correspondingly apply to tape reel unloading operations and tape reel unloading throughput, as will be understood by an individual having ordinary skill in the relevant art. Thus, a multi-reel handling apparatus can perform tape reel exchange / swap operations analogous or essentially identical to those described above in association with tape and reel machine unloading of tape from successive tape reels, such that components can be “de-taped” from the tape unloaded from each tape reel.

A tape and reel system that includes a tape and reel machine and a multi-reel handling apparatus configured for carrying multiple tape reels in accordance with an embodiment of the present disclosure can have a spatial footprint that is approximately the same as or which is not significantly larger than that of a conventional tape and reel system that requires an operator to manually perform a tape reel swap operation (e.g., to replace a full tape reel with an empty tape reel for loading thereof, or replace an empty tape reel with a full tape reel for unloading thereof) each time flexible tape transfer operations directed to a tape reel have been completed (whereby flexible tape transfer operations directed to a replacement tape reel cannot continue or occur until after such manual tape reel exchange).

For instance, a conventional tape reel handling apparatus configured for handling a single tape reel, and requiring manual removal of a tape reel disposed at the feeding position to position a next / new tape reel at the feeding position, can dispose a tape reel of a given size such that a particular tape reel structural feature (e.g., an outer edge of a tape reel flange, or an exposed surface of a tape reel winding hub) is located a particular distance d away from a plane through which the tape input / output axis extends (e.g., past a front edge of a support surface on which the tape and reel machine resides) during the transfer of the tape between the tape and reel machine and the tape reel. A multi-reel handling apparatus in accordance with an embodiment of the present disclosure can position a plurality of tape reels of this size such that the same structural feature of each of the plurality of tape reels (e.g., an outer edge of a flange, or an exposed surface of a tape reel winding hub) is located at the same, essentially the same, or approximately the same distance d away from this plane through which the tape input / output axis extends, while (a) the tape is being transferred between the tape and reel machine and one of the plurality of tape reels, and (b) the other(s) of the plurality of tape reels reside(s) at a standby position. Thus, a multi-reel handling apparatus in

accordance with an embodiment of the present disclosure can avoid increasing or significantly increasing the overall spatial footprint of conventional a tape and reel system.

Representative Multi-Reel Handling Apparatus Embodiments

5 A tape reel disposed at the feeding position can be defined as a ready, active, and/or feeder tape reel, because the flexible tape can be actively loaded / fed onto or unloaded / fed from such a ready / active tape reel. A tape reel disposed at a standby position can be defined as an inactive and/or standby tape reel, because the flexible tape is not loaded onto or unloaded from such an inactive / standby tape reel while it is disposed at the standby position. The
10 manner in which tape reels within a set or one or more pluralities of tape reels can be collectively displaced to thereby transition a given individual tape reel of the set or one or more pluralities of tape reels toward and to the feeding position to become the active tape reel while each other tape reel of the set or plurality of tape reels is transitioned toward and to a standby position to become or remain an inactive tape reel can vary depending upon
15 embodiment details. For instance, in some embodiments, multiple tape reels that share a common tape input / output axis or feeding position are collectively rotated or pivoted (e.g., circularly rotated) about a common pivot axis to thereby selectively / sequentially position a given individual tape reel at the feeding position and each other tape reel at a standby position. The pivot axis is perpendicular to the winding axes of the tape reels (or the shafts
20 of tape reel holding mechanisms that correspond to the tape reel winding axes), and can furthermore be parallel to the tape input / output axis or perpendicular to the tape input / output axis depending upon embodiment details, as further detailed below. Alternatively or additionally, in multiple embodiments, tape reels are collectively linearly displaced, shifted, or shuttled (e.g., laterally or horizontally shifted back and forth / left and right, and/or
25 vertically shifted up and down) relative to the tape input / output axis to thereby selectively / sequentially position one tape reel at the feeding position and another tape reel at a standby position.

For purpose of simplicity and to aid understanding, the description hereafter considers
30 representative embodiments of (a) rotatable / pivotable multi-reel handling apparatuses configured for carrying two or more tape reels (e.g., up to two tape reels, or up to four tape reels); (b) linearly (e.g., laterally or horizontally) shiftable / slidable multi-reel handling apparatuses configured for carrying two tape reels (e.g., up to two tape reels); and (c) linearly

shiftable as well as rotatable multi-reel handling apparatuses configured for carrying more than two tape reels (e.g., up to four tape reels).

Representative Rotatable Multi-Reel Handling Apparatuses

5 In a number of embodiments, a multi-reel handling apparatus is configured for collectively rotating multiple tape reels that share a single or common feeding position about a common pivot axis (e.g., which extends in a predetermined direction relative to the tape input / output axis). For purpose of simplicity and to aid understanding, the description that follows initially considers an configured for handling, carrying, or managing a single pair of tape
10 reels, after which embodiments capable of handling more than two tape reels are considered.

In a representative rotatable dual-reel handling apparatus, two tape reels are disposed / disposable in a parallel orientation relative to each other, such that (a) the winding axes of the two tape reels are coaxial or coincident with each other; (b) the two tape reels are separated
15 from each other by a gap (for instance, spanning a predetermined lateral or horizontal offset distance from the feeding position); (c) the pivot axis resides in the middle of the gap between the two tape reels, and is offset from the tape input / output axis (or equivalently, the two tape reels are disposed equidistant from each other on either side of the pivot axis, on a single or the same side of the tape input / output axis); (d) the two tape reels can be
20 collectively displaced (e.g., on a selective, selectable, or programmable basis) relative to the tape input / output axis or the feeding position by way of rotational or pivotal motion about the pivot axis; and (e) one of the tape reels can be positioned at the feeding position in alignment with the tape input / output axis, at which this tape reel can be loaded or unloaded with the flexible tape, while the other tape reel is positioned at the standby position at which
25 it can be removed or dismounted from the rotatable tape reel handling apparatus and replaced with another tape reel, for instance, while flexible tape is being wound onto or unwound from the tape reel disposed at the feeding position.

Such a dual-reel handling apparatus is configured for performing tape reel flip operations by
30 which the positions of the two tape reels with respect to the feeding position and the standby position can be automatically exchanged, flipped, or swapped by way of collectively displacing or rotating the two tape reels about the pivot axis. More particularly, for the dual-reel handling apparatus, as a result of each tape reel flip operation, the pair of tape reels is

rotated, turned, or flipped approximately 180 degrees (e.g., in a single or unified motion) about the pivot axis. As the pair of tape reels is rotated about the pivot axis, the winding axes of the two tape reels circumferentially travel in an arc around the pivot axis within a plane that is perpendicular to the pivot axis, until the locations of the tape reels with respect to the tape input / output axis have been exchanged / flipped / switched / swapped as a result of such rotation about the pivot axis. As a result, any given tape reel within a particular pair of tape reels carried by the dual-reel handling apparatus sequentially, successively, or alternately resides at (a) the feeding position, or (b) the standby position. Thus, if prior to a tape reel flip operation a first tape reel resides at the feeding position and a second tape reel resides at the standby position, immediately after the tape reel flip operation the first tape reel resides at the standby position and the second tape reel resides at the feeding position.

Pivot Axis Parallel to the Tape Input / Output Axis

FIGs. 1A – 1C are schematic illustrations showing portions of a representative rotatable tape reel handling apparatus 100 and particular portions of a tape and reel machine 10 in accordance with an embodiment of the present disclosure. The rotatable tape reel handling apparatus 100 shown in FIGs. 1A – 1C is configured for carrying two tape reels 110a,b in a side-by-side laterally separated arrangement, and is further configured for performing tape reel rotation / flip operations as described in detailed below. More particularly, FIG. 1A is a perspective view; FIG. 1B is a top view; and FIG. 1C is a side view of a dual-reel handling apparatus 100 and portions of the tape and reel machine 10 in accordance with an embodiment of the present disclosure. FIG. 2 is a schematic illustration showing a frontal view of portions of the dual-reel handling apparatus 100, indicating representative dual tape reel rotation about a pivot axis p during tape reel flip operations in accordance with an embodiment of the present disclosure, where the pivot axis p is parallel to and laterally offset from the tape input / output axis (e.g., the pivot axis is horizontal, and parallel to the tape input / output axis).

The dual-reel handling apparatus 100 interfaces with or forms a portion of the tape and reel machine 10. The tape and reel machine 10 can be conventional or substantially conventional (e.g., conventional, other than with respect to straightforward / minor structural modifications made thereto for purpose of accommodating or interfacing with a rotatable tape reel handling

apparatus, such as a dual-reel handling apparatus 100, in accordance with an embodiment of the present disclosure).

The tape and reel machine 10 includes a tape and reel module 20 that provides a tape track guide 22 (e.g., an adjustable width tape track guide 22) that provides or maintains a linear path along which or linear channel within which a flexible linear tape 12 is displaceable toward or away from the dual-reel handling apparatus 100, for instance, along or parallel to a tape input / output axis (e.g., an x axis) corresponding to the tape and reel module 20. In various embodiments, the flexible linear tape 12 includes (a) a carrier tape having a plurality of pockets or wells disposed therein along its length, in which components can be placed; and (b) a cover tape that overlays the carrier tape, and which seals the components inside the carrier tape wells in which they reside, in a manner readily understood by one having ordinary skill in the relevant art. The carrier tape can be supplied by a carrier tape reel (not shown) that is carried by a carrier tape module (not shown) of the tape and reel machine 10, and the cover tape can be supplied by a cover tape reel (not shown) that is carried by a cover tape module 14 of the tape and reel machine 10. An individual having ordinary skill in the relevant art will understand that for various tape and reel machines 10, the carrier tape is supplied from beneath the tape and reel module 20, and loops behind the tape and reel module 20 into the adjustable width tape track guide 22.

The tape and reel machine 10 includes or operates in association with a pick and place apparatus (not shown), for instance, a turret-based pick and place apparatus, which is configured for transferring individual components from a component source or component source locations into individual pockets of the carrier tape in association with a tape loading procedure; or transferring individual components from carrier tape pockets to component destinations or unloading locations in association with a tape unloading procedure. The tape and reel machine 10 can also include an in-pocket inspection module 16 configured for optically or visually inspecting the existence, position, and/or orientation of a component in each of the carrier tape's pockets. The tape and reel machine 10 additionally includes a sealing module 18 configured for sealing the cover tape onto the carrier tape after components have been placed in the carrier tape's pockets as the tape 12 is advanced along the tape input / output axis in association with tape reel loading operations; and unsealing the cover tape from the carrier tape in association with tape reel unloading and de-taping

operations. Thus, with respect to tape reel loading operations, an individual having ordinary skill in the relevant art will understand that the carrier tape supplied from the carrier tape reel and which has been feed into the adjustable width tape track guide 22 provides pockets into which components can be inserted. Once components have been inserted into such pockets, the components can be inspected (e.g., optically inspected). The carrier tape can then be sealed with a cover tape to thereby form the flexible tape 12, after which the flexible tape 12 can be loaded onto a tape reel 110 disposed at the feeding position. The tape and reel machine 10 further provides a conventional set of tape guide members or bars 24a,b (e.g., an upper tape guide member 24a and a lower tape guide member 24b) between and along which the flexible linear tape 12 can be guided into an empty tape reel 110, as will be understood by one having ordinary skill in the relevant art.

The tape and reel machine 10 additionally includes a controller or control unit (e.g., a computer, computer system, or computing device) having at least one processing unit and a memory in which one or more sets of program instructions reside, which can be executed by the processing unit(s) such that the tape and reel machine 10 and the dual-reel handling apparatus 100 perform tape reel loading / unloading and tape reel exchange / swap / flip operations in accordance with an embodiment of the present disclosure. The control unit can have data / signal communication, data storage, and information display devices / capabilities associated therewith, in a manner readily understood by those having ordinary skill in the relevant art.

Each tape reel 110a,b carried or carryable by the dual-reel handling apparatus 100 includes a first / outer / reference flange 112a and a counterpart second / inward flange 112b having a predetermined cross sectional area or diameter, and a tape winding hub or core 114a,b centrally disposed therebetween. Each tape winding hub 114a,b has a predetermined width corresponding to a width of flexible tape 12 that the tape reel 110 is intended to carry, such that the outward reference flange 112a and its counterpart inward flange 112b are disposed parallel or approximately parallel to each other across a separation distance correlated with or corresponding to the width of the flexible tape 12. The outward reference flange 112a serves as a reference surface for proper orientation (e.g., visual orientation) of a tape reel 110 disposed at the feeding position relative to the tape input / output axis, such that the flexible tape 12 and the components carried thereby have a predetermined orientation relative to the

tape reel's outer reference flange 112a, as further detailed below. While a given tape reel 110 is maintained at the feeding position, the flexible tape 12 can be positioned between the first / outer reference flange 112a and the second / inward flange 112b, and can extend between the tape reel 110 and the tape and reel module 20. The dual-reel handling apparatus 100 can
5 further include a tape retention bar or member 115a,b corresponding to each tape reel 110a,b, which can aid in preventing the flexible tape 12 from decoiling or unwinding from and falling off of the tape reel 110a,b during tape reel rotation / flip operations.

An individual having ordinary skill in the relevant art will recognize that each tape reel 110
10 carried by an apparatus 100 in accordance with an embodiment of the present disclosure has a corresponding winding axis ω about which the tape reel 110 can be spun, which can correspond to or be defined by a rotatable shaft 152 that carries the tape reel 110. For instance, a given winding axis ω can additionally or alternatively correspond to or be defined
15 along or as a central or longitudinal axis of a particular rotatable shaft 152, where the winding axis ω is perpendicular to a plane in which the rotation of the shaft 152 and/or the spinning of a tape reel 110 carried thereby occurs. An individual having ordinary skill in the relevant art will further understand that when a particular tape reel 110 is disposed at the feeding position, the rotatable shaft 152 that carries and spins the tape reel 110 is aligned
20 with respect to the feeding position, and hence this tape reel's winding axis ω is also aligned with respect to the feeding position for purpose of enabling communication or transfer (e.g., indexed displacement) of the flexible tape 12 between the tape reel 110 and the tape and reel machine 10. More specifically, when a selected tape reel 110 is disposed at the feeding position, a plane in which the tape input / output axis resides and which is parallel to each of
25 the tape reel's flanges 112 (e.g., which bisects or approximately bisects a tape winding hub or core 114 of the tape reel in a vertical or z axis direction) extends through the rotatable shaft 152 carrying this tape reel 110, and hence through the winding axis ω of the tape reel 110 disposed at the feeding position. Stated another way, a plane that bisects the width of the flexible tape 12 as the flexible tape 12 is fed to / from or wound around / unwound from the tape reel 110 at the feeding position extends through the rotatable shaft 152 carrying this tape
30 reel 110, and hence through this tape reel's winding axis ω . Stated yet another way, the rotatable shaft 152 carrying this tape reel 110 extends across a plane in which the tape input / output axis resides.

If the tape reel 110 at the feeding position is initially empty, the flexible tape 12 can be loaded or fed from the tape and reel module 20, between and along the upper tape guide element 24a and the lower tape guide element 24b extending between the tape reel's first and second flanges 112a,b, toward and to the tape reel's tape winding hub. The dual-reel handling apparatus 110 can spin the tape reel 110 disposed at the feeding position about the winding axis ω in a tape reel loading direction as the flexible tape 12 is fed from the tape and reel module 20 toward and to the tape reel 110, such that the flexible tape 12 can be wound around and loaded onto the tape reel 110. If the tape reel 110 at the feeding position is initially full, the flexible linear tape 12 can be fed from the tape reel 110 to the tape and reel module 20, and correspondingly unloaded from the tape reel 110 in association with the dual-reel handling apparatus 100 spinning the tape reel 110 about the winding axis ω in a tape reel unloading direction while the tape and reel module 20 concurrently displaces the tape away from the tape reel 110.

The dual-reel handling apparatus 100 includes a tape reel support structure or a set of bracket / frame elements configured for carrying two tape reels 110, and which is coupled to or carries a set of actuators. In various embodiments the dual-reel handling apparatus 100 includes (a) a first spin actuator or first actuator 150a configured for spinning a first tape reel 110a mechanically coupled thereto about a first winding axis ω_a when the first tape reel 110a is positioned at the feeding position, such that the flexible tape 12 can be loaded onto or unloaded from the first tape reel 110a; (b) a second spin actuator or second actuator 150b configured for spinning a second tape reel 110b mechanically coupled thereto about a second winding axis ω_b when the second tape reel 110b is positioned at the feeding position, such that the flexible tape can be loaded onto or unloaded from the second tape reel 110b; and (c) a multi-reel displacement actuator or a tape reel position exchange / pivot / switch / swap / flip actuator 170 (hereafter tape reel swap actuator, rotation based swap actuator, rotational swap actuator, or swap actuator 170 for purpose of brevity) configured for selectively or selectably and simultaneously pivoting or flipping the first and second actuators 150a,b, and hence the first and second tape reels 110a,b coupled thereto, about a tape reel flip axis or pivot axis ρ that in this configuration is parallel to and perpendicularly offset from (e.g., laterally offset to the left or right of) the tape input / output axis, midway between the first

and second tape reels 110a,b. The tape reel flip / pivot axis p is perpendicular to each tape reel's winding axis $\omega_{a,b}$.

The first actuator 150a is mechanically coupled or linked to a first rotatable rod or shaft 152a to which the first tape reel 110a is securely mounted or mountable in a conventional manner, such as by way of a first conventional tape reel holding mechanism or holder 153a. Similarly, the second actuator 150b is mechanically coupled or linked to a second rotatable rod or shaft 152b to which the second tape reel 110 is securely mounted or mountable in a conventional manner, such as by way of a second conventional tape reel holder 153b. Each tape reel holder 153 enables secure attachment of a tape reel 110 to a corresponding shaft 152 and removal of the tape reel 110 from the shaft 152. Each actuator 150a,b can be selectively or selectably activated, such as by way of the control unit coupled or corresponding to the tape and reel machine 10, to rotate the shaft 152a,b corresponding to the actuator 150a,b about its winding axis $\omega_{a,b}$ in the tape reel loading direction or the tape reel unloading direction. Rotation of a given shaft 152a,b to which a tape reel 110a,b is mounted results in spinning or circumferential rotation of the tape reel 110a,b about its corresponding winding axis $\omega_{a,b}$. Hence, when the first and second tape reels 110a,b are mounted to the first and second shafts 152a,b, the tape reel pivot axis p is perpendicular to each such shaft 152a,b.

The first and second actuators 150a,b can be carried by a set of actuator support members or bracket or frame members, such as a common bracket, frame, frame structure, chassis, platform, stage, scaffold, case, or holder 160, in one or more manners. For instance, in several embodiments, the first and second actuators 150a,b are supported or disposed on the frame 160 relative to each other in an "over / under" configuration, such as in a symmetric or generally symmetric manner relative to the frame 160 and/or each other. Thus, the first actuator 150a can be supported by or reside on a first or upper side of the frame 160, and the second actuator 150b can be supported by or reside on a second or lower / under side of the frame 160 that is opposite to the first side of the frame 160. The frame 160 can also carry a set of tape reel drive elements or mechanisms 154, such as wheels / pulleys, belts / chains, and/or gears, corresponding to each actuator 150a,b, that mechanically each actuator 150a,b to the first and second shafts 152a,b, respectively. Taken together, each actuator 150a,b and a set of tape reel drive elements 154 associated therewith can be defined as a set of tape reel

actuation elements. In various embodiments, the first and second actuators 150a,b, their respective tape reel drive elements 154, and the frame 160 reside between the first and second shafts 152a,b, and more particularly between the first and second tape reels 110a,b when the tape reels 110a,b are mounted to the shafts 152a,b.

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The dual-reel handling apparatus 100 further includes a support structure, member, or element 102 that carries or supports the swap actuator 170, and which is typically mechanically / structurally couplable / coupled to the tape and reel machine 10. In various embodiments, the support member 102 is disposed or extends away from the tape and reel machine 10 in a direction parallel to the tape input / output axis. For instance, the support member 102 can have a central axis that extends along a direction parallel to or coincident with portions of the tape reel pivot axis p .

In several embodiments, the swap actuator 170 is mechanically coupled or linked by an exchange / pivot / switch / swap / flip rod or shaft 172 (hereafter swap shaft 172) to the frame 160 that carries the first and second actuators 150a,b. A central axis of the swap shaft 172 is coincident with a center point or centroid of the frame 160, and defines or is coincident with the tape reel pivot axis p . Thus, rotation of the swap shaft 172 causes rotation of the frame 160, and consequently collective or simultaneous rotation of the first and second actuators 150a,b, the first and second shafts 152a,b, and any tape reels 110a,b mounted thereto, about the tape reel pivot axis p . In other words, the frame 160, and the structures / devices / elements supported or carried thereby, are rotatable by way of rotation of the swap shaft 172 corresponding to the swap actuator 170. Therefore, the swap actuator's rotation of the swap shaft 172 causes rotation of the first and second tape reels 110a,b about the tape reel pivot axis p , such that the outward-most or outermost ends or tips of the first and second shafts 152a,b, which are perpendicular to and directed away from the tape reel pivot axis p , traverse or follow an arcuate path corresponding to a circle that resides in a plane which is perpendicular to and bisected by the tape reel pivot axis p . In view of the foregoing, the swap actuator 170 can also be referred to as a frame rotation actuator; and the swap shaft 172 can correspondingly be referred to as a frame rotation shaft.

To further aid understanding, aspects of a representative set of tape reel swap or flip operations performed during successive tape reel loading operations are described in detail

hereafter with reference to FIG. 2 and additional reference to FIGs. 3A – 3B. For purpose of simplicity, at the outset or onset of the successive tape reel loading operations, the first tape reel 110a and the second tape reel 110b are each mounted to the dual-reel handling apparatus 110, and are each empty.

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During a first portion or phase of the successive tape reel loading operations, the dual-reel handling apparatus 100 disposes or maintains the currently empty first tape reel 110a at the feeding position, and the currently empty second tape reel 110b at the standby position. The first actuator 150a can thus be activated to spin the first tape reel 110a about the first winding
10 axis ω_a in the loading direction while the tape and reel machine 100 feeds the flexible tape 12 to the first tape reel 110a, thereby loading the first tape reel 110a with the flexible tape 110.

Once the first tape reel 110 is full, for instance, as automatically determined by a predetermined time period that has elapsed following initiation of feeding the flexible tape 12 to the first tape reel 12, and/or automatically detected by way of a conventional sensor (e.g.,
15 an optical sensor) carried by the dual-reel handling apparatus 100, the tape and reel machine 10 interrupts feeding of the flexible tape 12 to the first tape reel 110a, and activates an automatic tape cutting module 30 that forms a portion of the tape and reel machine 10. Any length of flexible tape 12 that remains between the tape cutting module 30 and the first tape
20 reel 110a can be taken up by and loaded onto the first tape reel 110a as a result of continued spinning of the first tape reel 110a. After a limited / brief / predetermined time interval following the activation of the tape cutting module 30, the first actuator 150a (and/or a tape reel braking mechanism, not shown) halts the spinning of the now-full first tape reel 110a. Thus, after the first tape reel 110a is loaded with the flexible tape 12, the first tape reel 110a
25 is full, as illustrated in FIG. 3A. In some embodiments, a remaining, trailing, or loose end of the tape 12 carried by the full first tape reel 110a can be manually secured to a portion of the tape 12 wound about the first tape reel 110a and/or secured to the first tape reel 110a itself. In other embodiments, such a remaining, trailing, or loose end of the tape 12 can be automatically held against a portion of the tape 12 wound about the first tape reel 110 and/or
30 the first tape reel 110a, such as by way of a compression or clamping mechanism (e.g., which can be spring loaded / activated) that is carried by or which forms a portion of the tape retention bar 115a corresponding to the first tape reel 110a. During the above-described first

phase of the successive tape reel loading operations, the second tape reel 110b can remain stationary.

In a second phase of the successive tape reel loading operations, e.g., which is performed
5 directly or immediately after the first actuator 150a ceases spinning the first tape reel 110a
(and once any remaining, trailing, or loose end of the tape 12 has been secured in place as
necessary, such as described above), the swap actuator 170 is automatically activated to
perform the set of tape reel flip operations by simultaneously rotating, pivoting, or flipping
the first and second tape reels 110a,b about the tape reel pivot axis ρ , through or across a total
10 rotational, pivot, or flip angle, which for the case of the dual-reel handling apparatus 100 is
180 degrees. The 180 degree flip angle can be defined as a number of degrees through which
the swap shaft 172 rotates during the set of tape reel flip operations. Correspondingly, the
180 degree flip angle can be defined as an angular span or circumferential number of degrees
through which (a) the outward-most or outermost end or tip of the first shaft 152a rotates
15 from the feeding position to the standby position, or equivalently, (b) the outward-most or
outermost end or tip of the second shaft 152b rotates from the standby position to the feeding
position during the set of tape reel flip operations. In various embodiments, the swap
actuator 170 includes a rotational encoder that facilitates or enables precise control over the
angular rotation of the swap shaft 172, and accurate detection of when rotation of the tape
20 reels 110a,b through the 180 degree flip angle is complete, such that the second tape reel
110b is properly or precisely aligned with respect to the tape input / output axis. In some
embodiments, the dual-reel handling apparatus 100 can include one or more sensors (e.g.,
optical, electrical, and/or mechanical sensors) configured for detecting complete rotation of
the tape reels 110a,b through the 180 degree flip angle, and providing corresponding
25 feedback for controlling the swap actuator 170.

FIG. 2 is a schematic illustration showing simultaneous rotation of the first and second tape
reels 110a,b about the pivot axis ρ through a representative intermediate angle that is less
than the 180 degree flip angle, during the rotation of the first and second tape reels 110a,b
30 through or across the 180 degree flip angle. As indicated in FIG. 2, the first and second tape
reels 110a,b are rotated or circumferentially displaced together about the tape reel pivot axis
 ρ , away from their initial locations at the feeding position and the standby position,
respectively; as they are rotated through the 180 degree flip angle.

After the swap actuator 170 has rotated the first and second tape reels 110a,b through the 180 degree flip angle, the now-full first tape reel 110a is disposed at the standby position, and the presently empty second tape reel 110b is disposed at the feeding position in the manner indicated in FIG. 3B, and the swap actuator 170 interrupts or ceases further rotation of the first and second tape reels 110a,b during this second phase of the successive tape reel loading operations. Thus, as shown in FIG. 3B, after the dual-reel handling apparatus 110 has performed this set of tape reel flip operations, the first and second tape reels 110a,b have been automatically repositioned such that their original locations have been switched, exchanged, or swapped.

During a third phase of the successive tape reel loading operations, the second actuator 150b can be actuated to facilitated loading of the second tape reel 110b with the flexible tape 12 in a manner essentially identical or analogous to that described above for the loading of the first tape reel 110a. While the second tape reel 110b is being loaded with the flexible tape 12, an operator can remove or dismount the first tape reel 110a from the first shaft 152a, and replace the first tape reel 110a with another empty tape reel 110, for instance, a third tape reel 110.

Once loading of the second tape reel 110b with the flexible tape 12 is complete (e.g., the second tape reel 110b is full), the tape and reel machine 10 can activate the tape cutting module 30 in the manner indicated above; the second tape reel 110b can be spun about the second winding axis ω_b to take up any length of flexible tape 12 that remains between the cutting module 30 and the second tape reel 110b; and the second actuator 150b (and/or a tape reel braking mechanism) can then halt the spinning of the second tape reel 110b. Additionally, an exposed portion of the flexible tape's length can be secured in position relative to the second tape reel 110b, in a manner essentially identical to that described above.

In a fourth phase of the successive tape reel loading operations, e.g., which is performed directly or immediately after the second actuator 150b ceases spinning of the second tape reel 110b, the swap actuator 170 can once again be activated to perform the set of tape reel flip operations to collectively rotate the now-full second tape reel 110b and the presently empty

third tape reel 110 about the tape reel pivot axis ρ across the 180 degree flip angle, in a manner essentially identical or analogous to that described above, until the second tape reel 110b is once again disposed at the standby position and the third tape reel 110 is disposed at the feeding position, ready to be loaded with the flexible tape 12.

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The foregoing successive tape reel loading operations can be performed (e.g., repeatedly or cyclically performed) across a sequence of multiple tape reels 110, such that each tape reel 110 is (a) mounted to the dual-reel handling apparatus 100; (b) automatically loaded with the flexible tape 12 while disposed at the feeding position; (c) automatically rotated through the 180 degree flip angle to the standby position, such that it can be removed or dismounted from the dual-reel handling apparatus 100; and then (d) replaced by or swapped out for another empty tape reel 110.

In view of the foregoing description, an individual having ordinary skill in the relevant art will understand that when any given tape reel 110 mounted to the dual-reel handling apparatus 100 resides at the feeding position, and hence is serving as the active / feeder tape reel 110, its outward reference flange 112a should face outward, away from the standby position (the frame 160, the pair of actuators 150a,b carried thereby, and the tape reel pivot axis ρ), such that the flexible tape 12 loaded onto or unloaded from the feeder tape reel 110, and hence the components carried thereby, have a predetermined proper orientation relative to the tape and reel machine 10. Similarly, when a tape reel 110 mounted to the dual-reel handling apparatus 100 resides at the standby position, and hence is serving as the inactive or standby tape reel, its outward reference flange 112a should face outward, away from the feeding position, such that when this inactive / standby tape reel 110 is flipped to the feeding position and becomes the active / feeder tape reel 110, the flexible tape 12 loaded onto or unloaded therefrom and the components carried thereby have a predetermined proper orientation relative to the tape and reel machine 10.

An individual having ordinary skill in the relevant art will readily understand that successive tape reel unloading operations, which involve a set of tape reel flip operations, can be performed in a manner analogous to that described above.

In a number of embodiments, a rotatable tape reel handling apparatus 100 in accordance with an embodiment of the present disclosure can be configured for carrying more than two tape reels 110 at any given time, such as up to four tape reels 110. For instance, FIGs. 4A – 4E are schematic illustrations showing a group of four tape reels 110a-d carried by a rotatable tape reel handling apparatus 100 in accordance with an embodiment of the present disclosure, as viewed looking toward the rotatable tape reel handling apparatus 100 along the pivot axis ρ towards a swap shaft 170 about which the four tape reels 110a-d are collectively rotatable about the pivot axis ρ , such that one of the four tape reels 110a-d can be disposed at a feeding position shared by or among the four tape reels 110a-d while the others of the four tape reels 110a-d are disposed at standby positions offset or away from the feeding position.

In a manner analogous, similar, or generally similar to that described above, the rotatable tape reel handling apparatus 100 includes (a) a set of tape reel actuation elements configured for selectively spinning one of the first through fourth tape reels 110a-d while it is disposed at the feeding position and the others of the first through fourth tape reels 110a-d are disposed at standby positions away from the feeding position; and (b) a tape reel swap actuator. For purpose of clarity to aid understanding, in FIGs. 4A – 4E a set of actuation elements (e.g., including four individual actuators) for driving or spinning each of the four tape reels 110a-d and an associated swap actuator are not shown. An individual having ordinary skill in the relevant art will recognize that various types of actuators and/or actuator arrangements can be utilized for selectively spinning the tape reels 110a-d or collectively rotating or swapping the positions of the tape reels 110a-d, such as a number of rectangular, cylindrical, low profile / disc / flat / pancake, hub, or other type(s) of actuators or motors, possibly in association with individual or shared power or force transmission mechanisms such as pulleys / wheels, belts / chains, gears, shafts / rods, and/or other elements.

For instance, in the embodiment shown in FIGs. 4A – 4E, the rotatable tape reel handling apparatus 100 can include a first through a fourth actuator (not shown) configured for respectively rotating the first through the fourth tape reel 110a-d about each such tape reel's winding axis ω_{a-d} . The winding axes $\omega_{a,c}$, $\omega_{b,d}$ of individual tape reels 110a,c, 110b,d disposed opposite each to other can be coincident with each other, in a manner readily understood by individuals having ordinary skill in the relevant art. Each of the first through

the fourth actuators can be carried by a common support structure or frame, in a manner analogous to that described above. Such a rotatable tape reel handling apparatus 100 further includes a swap actuator (not shown) coupled to the swap shaft 170 corresponding to the pivot axis ρ , which is configured for collectively rotating the first through the fourth tape reels 110a-d, and hence the set of actuators configured for spinning the first through fourth tape reels 110a-d, about the pivot axis ρ on a selective / selectable / programmable basis, in a manner readily understood by an individual having ordinary skill in the relevant art.

In the embodiment shown in FIG. 4A – 4E, the winding axis ω_{a-d} of any given tape reel 110a is perpendicular to the pivot axis ρ , and is offset 90 degrees from the winding axis ω_{a-d} of each other tape reel 110b-d. In a manner analogous to that described above, as indicated in FIG. 4A, the rotatable tape reel handling apparatus can 100 selectively / selectably dispose four empty tape reels 110a-d such that a current active / feeder tape reel 110a is located at the feeding position 200, while a first inactive / standby tape reel 110b is located at a first standby position 210a; a second inactive / standby tape reel 110c is located at a second standby position 210b; and a third inactive / standby tape reel 110d is located at a third standby position 210b.

Directly or immediately after flexible tape transfer operations directed to the current active / feeder tape reel 110a disposed at the feeding position 200 are complete (e.g., the current active / feeder tape reel 110a has been loaded with the flexible tape 12), the rotatable tape and reel handling apparatus 100 automatically rotates the group of four tape reels 110a-d in a predetermined direction (e.g., clockwise) about the pivot axis ρ through a pivot angle of 90 degrees to thereby transfer one tape reel 110a away from the feeding position 200 toward and to a predetermined standby position 210c, while simultaneously transferring another tape reel 110b away from its standby position 210a toward and to the feeding position 200.

For instance, if each of the four tape reels 110a-d is initially empty as shown in FIG. 4A and rotation about the pivot axis ρ occurs in a clockwise direction, after the current active / feeder tape reel 110a is full as indicated in FIG. 4B, the rotatable tape reel handling apparatus 100 rotates the group of four tape reels 110a-d in a clockwise direction about the pivot axis ρ across the 90 degree pivot angle such that the most recently filled tape reel 110a is rotated to

the third standby position 210c; a next empty tape reel 110b (disposed immediately counter-clockwise to the most recently filled tape reel 110b) that was most recently located at the first standby position 210b is rotated to the feeding position 200, such that it becomes the current active / feeder tape reel 110; and the tape reels 110c-d that were located at the second and third standby positions 210b,c are respectively rotated to the first and second standby positions 210a,b, as indicated in FIG. 4C.

Similarly, after flexible tape transfer operations directed to the current active / feeder tape reel 110b are complete (e.g., the current active / feeder tape reel 110b has been loaded with the flexible tape 12), such as indicated in FIG. 4D, the rotatable tape reel handling apparatus 100 rotates the group of four tape reels 110a-d in a clockwise direction about the pivot axis p through the 90 degree pivot angle such that the most recently filled tape reel 110b is transferred from the feeding position 200 to the third standby position 210c; the filled tape reel 110a that was previously positioned at the third standby position 210c is transferred to the second standby position 210b; the empty tape reel 110c that was previously positioned at the second standby position 210b is transferred to the first standby position 210a; and the empty tape reel 110d (disposed immediately counter-clockwise to the most recently filled tape reel 110b) is transferred from the first standby position 210a to the feeding position 200 to thereby become the current active / feeder tape reel 110. Such collective rotation of the four tape reels 110a-d is indicated in FIG. 4E, which illustrates two filled tape reels 110a,b and two empty tape reels 110c,d.

As indicated in FIGs. 4A – 4E, when a tape reel 110 resides at the second standby position 210b, the tape reel's first and second shanks 112a,b are maintained in a vertical orientation with respect to a support surface such as a floor on which the tape and reel machine 10 resides. Thus, in various embodiments, when a filled tape reel 110a arrives at the second standby position 210b, it can easily be removed or dismounted from the rotatable tape reel handling apparatus 100, and replaced with a new empty tape reel 110. Such removal of a tape reel 110a from the second standby position 210b and replacement of this tape reel 110a with another (e.g., empty) tape reel can occur concurrent with flexible tape transfer operations (e.g., tape reel loading) directed to current active / feeder tape reel 110c.

In certain embodiments, a tape reel 110 can be manually or automatically removed from the rotatable tape reel handling apparatus 100 when the tape reel 110 is disposed at the third standby position 210c; and/or a tape reel 110 can be manually or automatically mounted to the rotatable tape reel handling apparatus 100 when the tape reel 110 is disposed at the first
5 standby position 210a.

The foregoing process can continue on a repeated, cyclical, or ongoing basis, such that flexible tape transfer operations directed to a current active / feeder tape reel 110 located at the feeding position can occur in an uninterrupted manner while a tape reel 110 located at a
10 standby position is removed and replaced.

Pivot Axis Perpendicular to the Tape Input / Output Axis

FIGs. 5A – 5E illustrate representative rotatable multi-reel handling apparatuses 300 configured for carrying a plurality of tape reels 110 in accordance with particular
15 embodiments of the present disclosure, in which a pivot axis ρ about which the plurality of tape reels 110 can be collectively rotated is (a) perpendicular to the tape input / output axis, as well as (b) perpendicular to the winding axis ω of each of the plurality of tape reels 110, or equivalently, perpendicular to each of a plurality of tape reel holder shafts 152 (where each shaft 152 is configured for carrying a tape reel 110 of the plurality of tape reels 110, such that
20 the tape reel 110 is spinnable about the shaft 152). The pivot axis ρ can thus be defined to be vertical, e.g., with respect to a floor or the ground.

In a manner analogous to that described above, a rotatable multi-reel handling apparatus 300 is configured for (a) carrying a plurality of tape reels 110 such that one of the plurality of tape
25 reels 110 can be disposed at a feeding position 200 shared by or common to the plurality of tape reels 110 while each other of the plurality of tape reels is disposed at a standby position that is offset or away from the feeding position 200; and (b) collectively rotating the plurality of tape reels 110 (e.g., on a selective, selectable, or programmable basis) in order to sequentially dispose each of the plurality of tape reels 110 at the feeding position 200 during
30 tape reel loading / unloading operations directed thereto while each other of the plurality of tape reels 110 is disposed at a standby position. The rotatable multi-reel handling apparatus 300 includes a set of tape reel actuation elements configured for selectively spinning a given

tape reel 110 disposed at the feeding position 200, and a tape reel swap actuator 170 configured for selectively rotating the plurality of tape reels 110, in a manner analogous or similar to that described above as will be readily understood by an individual having ordinary skill in the art.

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FIG. 5A illustrates a rotatable dual-reel handling apparatus 300 in accordance with an embodiment of the present disclosure, which is configured for carrying up to two tape reels, e.g., a first tape reel 110a and a second tape reel 110b, by way of first and second shafts 152a,b on which the first and second tape reels 110a,b can be mounted. The rotatable dual-reel handling apparatus 300 includes a set of actuator support or bracket / frame members, for instance, a frame 160 that carries the set of tape reel actuation elements, such as a first and second actuator 150a,b that are respectively configured for selectively rotating the first and second tape reels 110a,b by way of associated tape reel drive elements that are coupled to the first and second shafts 152a,b. The apparatus 300 further includes a multi-reel displacement actuator or swap actuator 170 having a swap shaft 172 to which the frame is coupled 160 such that the swap actuator 170 can simultaneously rotate the first and second tape reels 110a,b (e.g., on a selective, selectable, or programmable basis) about the pivot axis p . The swap shaft 172 thus corresponds to or defines the pivot axis p . The pivot axis p is perpendicular or essentially perpendicular to the tape input / output axis, and is parallel or essentially parallel to a plane that bisects a winding hub 114a,b of each tape reel 110a,b carried by the apparatus 300, or equivalently, perpendicular or essentially perpendicular to a plane that bisects the shaft 152a,b on which each tape reel 110a,b is mounted. Thus, in the embodiment shown, the pivot axis extends along a vertical direction p .

FIGs. 5B – 5E are a top views showing portions of the rotatable dual-reel handling apparatus 300 during a representative sequence of tape transfer operations in accordance with an embodiment of the present disclosure, which for purpose of simplicity and to aid understanding corresponds to tape reel loading operations. As indicated in FIG. 5A, when the first tape reel 110a is disposed at the feeding position 200, the tape 12 can be displaced along the tape input / output axis and transferred between the first tape reel 110a and the tape and reel machine 10, while the second tape reel 110b remains at a standby position that is laterally or horizontally offset by a predetermined distance from the tape input / output axis. Once tape reel loading operations directed to the first tape reel 110a are complete (e.g., the

first tape reel 110a is full), the swap actuator 170 can rotate the first and second tape reels 110a,b about the pivot axis in a manner indicated in FIG. 5C (e.g., across an angle of approximately 180 degrees) to thereby swap the positions of the first and second tape reels 110a,b such that the second tape reel 110b is disposed at the feeding position 200 and the first
5 tape reel 110a is disposed at the standby position. After the second tape reel 110b has been disposed at the feeding position 200, tape reel loading operations directed to the second tape reel 110b can be initiated (e.g., automatically initiated). While the second tape reel 110b is being loaded with the tape 12, the first tape reel 110a can be removed from the apparatus 300, and a subsequent or third tape reel 110c, which is empty, can be mounted to the
10 apparatus 300. Such removal of the full first tape reel 110a and replacement thereof with the third tape reel 110c can occur without delaying or interrupting the loading of the second tape reel 110b, thus maintaining or enhancing tape and reel machine throughput.

After tape transfer operations directed to the second tape reel 110b are complete (e.g., the
15 second tape reel 110b is full), the swap actuator 170 can collectively rotate the second and third tape reels 110b,c about the pivot axis ρ (e.g., across an angle of approximately 180 degrees) to dispose the third tape reel 110c at the feeding position 200 and simultaneously dispose the second tape reel at the standby position, in a manner essentially identical to that described above. Once the third tape reel 110c is disposed at the feeding position 200, tape
20 transfer operations directed thereto can commence, and the second tape reel 110b can be replaced with an empty fourth tape reel (not shown) without delaying or interrupting the initiation or performance of tape transfer operations directed to the third tape reel 110c, in a manner that individuals having ordinary skill in the relevant art will readily understand in view of the description herein. An individual having ordinary skill in the relevant art will
25 also readily understand the manner in which a sequence of tape reel unloading operations can be performed with respect to a plurality of tape reels 110.

A rotatable multi-reel handling apparatus 300 in accordance with an alternate embodiment of the present disclosure can be configured for carrying additional tape reels, such as a first
30 through a fourth tape reel 110a-d in a manner analogous to that described above with reference to FIGs. 4A – 4E.

Representative Tape Reel Shuttling Apparatuses

FIGs. 6A – 6F illustrate representative aspects of a dual-reel shuttling apparatus 400 configured for laterally or horizontally displacing, shifting, or shuttling up to two tape reels 110 to facilitate or enable repeated / cyclical / ongoing or continual / continuous tape reel transfer operations across multiple tape reels 110 (e.g., two, ten, twenty, fifty, one hundred, or more tape reels 110) in accordance with an embodiment of the present disclosure. In a manner analogous or essentially identical to that described above, the tape reel shuttling apparatus 400 includes a first and a second shaft 152a,b on which a pair of tape reels 110, such as a first and a second tape reel 110a,b, can be mounted. The first and second shafts 152a,b are coupled to a set of tape reel actuation elements, for instance, a first and a second actuator 150a,b, respectively, which can selectively rotate (e.g., by way of a set of tape reel drive elements or mechanisms) a given tape reel 110a disposed at the feeding position 200 while the other tape reel 110b is disposed at a standby position that is laterally or horizontally offset from the feeding position 200. The set of tape reel actuation elements can be carried by a support structure such as a set of brackets or a frame 160, in a manner analogous to that described above.

As indicated in FIG. 6A, the dual-reel shuttling apparatus 400 includes a multi-reel displacement actuator or shift / shuttle actuator 175 configured for laterally or horizontally displacing the frame 160 on a selective, selectable, or programmable basis to thereby dispose the first tape reel 110a at the feeding position 200 in alignment with the tape input / output axis while simultaneously disposing the second tape reel 110b at a first or left side standby position that is laterally or horizontally offset a predetermined distance away from the feeding position 200 out of alignment with the tape input / output axis on a first or left side of the tape input / output axis, respectively. As indicated in FIG. 6B, once tape transfer operations directed to the first tape reel 110a disposed at the feeding position 200 are complete, the shuttle actuator 175 can simultaneously or collectively displace the two tape reels 110a,b in a lateral or horizontal direction such that the second tape reel 110b is disposed at the feeding position 200 in alignment with the tape input / output axis, and the first tape reel 110a is concurrently disposed at a second or right side standby position that is laterally or horizontally offset a predetermined distance away from the feeding position 200 out of alignment with the tape input / output axis on a second or right side of the tape input / output axis, respectively. In particular embodiments, the shuttle actuator 175 can include or is an electromechanical or pneumatic linear actuator, which is coupled to or which has a shuttle

shaft 176 and/or other frame displacement mechanism by which the frame 160 is displaceable along the shuttle axis σ . In other embodiments, the shuttle actuator 175 can be configured for shifting or shuttling the first and second tape reels 110a,b in either direction along the shuttle axis σ in a different manner, such as by way of a set of gears, wheels, and/or rollers (not shown) that displace a support structure such as a bar or platform (not shown) or frame 160 that carries the set of tape reel actuation elements and the first and second shafts 152a,b (and accordingly, any tape reel(s) 110a,b mounted thereto).

In view of the foregoing, the shuttle actuator 175 is configured for linearly, laterally, or horizontally shifting or shuttling a plurality of tape reels 110a,b carried by the dual-reel shuttling apparatus 400, or equivalently, the first and second shafts 152a,b, on a selective, selectable, or programmable basis along a shuttle axis σ that is parallel to a plane that bisects or approximately bisects the first and second shafts 152a,b. Stated equivalently, the shuttle actuator 175 is configured for selectively shifting or shuttling the first and second shafts 152a,b and the tape reel(s) 110 carried thereby in a first direction and an opposite second direction along the shuttle axis σ , which is parallel to each tape reel's winding axis ω or perpendicular to a plane that bisects or approximately bisects the winding hub 114 of each tape reel 110 carried by the dual-reel shuttling axis 400.

With respect to a repeated / cyclical / ongoing or continual / continuous sequence of tape transfer operations, as indicated in FIG. 6C while the first tape reel 110a is disposed at the feeding position 200 and the second tape reel 110b is disposed at the left standby position on the left side of the tape input / output axis, tape transfer operations directed to the first tape reel 110a can occur. For purpose of simplicity, hereafter the tape transfer operations are considered to be tape reel loading operations. Once tape transfer operations directed to the first tape reel 110a are complete (e.g., the first tape reel 110a is full), the shuttle actuator 175 can be activated to simultaneously or collectively displace the first and second tape reels 110a,b to the right along the shuttle axis σ , for instance, in a representative manner shown in FIG. 6D, such that the first tape reel 110a is shifted out of alignment with the feeding position 200 as the second tape reel 110b is shifted away from the left standby position toward the feeding position 200. Once the second tape reel 110b is disposed at the feeding position 200 and the first tape reel 110a is disposed at the right standby position in a manner

indicated in FIG. 6E, tape transfer operations directed to the second tape reel 110b can commence. While the second tape reel 110b is being loaded with the flexible tape 12, the first tape reel 110a can be removed from the dual-reel shuttling apparatus 400 and replaced with an empty third tape reel 110c in a manner shown in FIG. 6F, without delaying or
5 interrupting the tape transfer operations directed to the second tape reel 110b.

After tape transfer operations directed to the second tape reel 110b are complete (e.g., the second tape reel 110b is full), the shuttle actuator 175 can simultaneously or collectively displace the second and third tape reels 110b,c to the left along the shuttle axis σ , such that
10 the second tape reel 110b is shifted out of alignment with the feeding position 200 as the third tape reel 110c is shifted away from the right standby position toward the feeding position 200. Once the third tape reel 110c is disposed at the feeding position 200 and the second tape reel 110b is disposed at the left standby position, tape transfer operations directed to the third tape reel 110c can commence. While the third tape reel 110c is being
15 loaded with the flexible tape 12, the second tape reel 110b can be removed from the dual-reel shuttling apparatus 400 and replaced with an empty fourth tape reel (not shown), without delaying or interrupting the tape transfer operations directed to the third tape reel 110c.

Representative Rotatable and Linearly Shiftable Multi-Reel Handling Apparatuses

FIG. 7A illustrates a multi-reel rotation and shuttling apparatus 500 in accordance with a representative embodiment of the present disclosure, which is configured for (a) carrying and automatically managing tape transfer operations directed to a first plurality of tape reels 111a by way of a first rotatable multi-reel handling apparatus 300a; (b) carrying and automatically managing tape transfer operations directed to a second plurality of tape reels 111b by way of
25 a second rotatable multi-reel handling apparatus 300b; and (c) automatically linearly, laterally, or horizontally displacing, shifting, or shuttling the first plurality of tape reels 111a and the second plurality of tape reels 111b with respect to a feeding position 200 that is common to or shared by each tape reel 110 of the first and second pluralities of tape reels 111a,b. Each of the first plurality of tape reels 111a,b includes at least two tape reels 110, but
30 can include additional tape reels 110 in a manner analogous or essentially identical to that described above.

The multi-reel rotation and shuttling apparatus 500 includes a set of actuation elements configured for selectively spinning a particular tape reel 110 disposed at the feeding position 200 in alignment with the tape input / output axis, while other tape reels 110a,b within the first and second pluralities of tape reels 111a,b are disposed at standby positions away from the feeding position 200 out of alignment with the tape input / output axis. For instance, the multi-reel rotation and shuttling apparatus 500 can include a first set of actuation elements configured for selectively rotating each tape reel 110 within the first plurality of tape reels 111a when the tape reel 110 resides at the feeding position 200; and a second set of actuation elements configured for selectively rotating each tape reel 110 within the second plurality of tape reels 111b when the tape reel 110 resides at the feeding position 200. Each rotatable multi-reel handling apparatus 300a,b can have a structure that is identical, essentially identical, analogous, or similar to an embodiment described above with reference to FIGs. 5A – 5F. For instance, the first set of actuation elements can include first and second actuators 150a,b carried by a frame 160 and coupled to first and second shafts 152a,b, each of which is configured for spinning a tape reel 110 carried thereby when the tape reel is disposed at the feeding position; and the second set of actuation elements can include counterpart first and second actuators 150a',b' carried by a counterpart frame 160' and coupled to counterpart first and second shafts 152a',b', each of which is configured for spinning a tape reel 110 carried thereby when the tape reel 110 is disposed at the feeding position. The first rotatable multi-reel handling apparatus 300a can include a swap actuator 170 configured for selectively rotating the frame 160 of the first rotatable multi-reel handling apparatus 300a; and the second rotatable multi-reel handling apparatus 300b can include a counterpart swap actuator 170' configured for selectively rotating the counterpart frame 160' of the second rotatable multi-reel handling apparatus 300b, in a manner readily understood by individuals having ordinary skill in the relevant art.

The multi-reel rotation and shuttling apparatus 500 also includes a shuttle actuator 175 configured for simultaneously or collectively displacing the first and second pluralities of tape reels 111a-b along a shuttle axis σ , such as by way of a set of gears, wheels, and/or rollers 177 that is coupled to a plate or platform 178 that supports or carries each rotatable multi-reel handling apparatus 300a,b at a particular separation distance apart from each other. The shuttle actuator 175 can be configured for selectively, selectably, or programmably

displacing the platform 178 in either direction along the shuttle axis σ , such that (a) the first rotatable multi-reel handling apparatus 300a can be disposed relative to the feeding position 200 in a manner that enables a sequence of tape transfer operations directed to the tape reels 110 carried thereby, while the second rotatable multi-reel handling apparatus 300b is disposed at a first or left unloading / waiting zone or position on a first or the left side of the feeding position 200 away from the first rotatable multi-reel handling apparatus 300a; and (b) the second rotatable multi-reel handling apparatus 300b can be disposed relative to the feeding position 200 in a manner that enables a sequence of tape transfer operations directed to the tape reels 110 carried thereby, while the first rotatable multi-reel handling apparatus 300a is disposed at a second or right unloading / waiting zone or position on a second or right side of the feeding position 200 away from the second rotatable multi-reel handling apparatus 300b.

With respect to tape reel loading operations, each of the first plurality of tape reels 111a carried by the first rotatable tape reel handling apparatus 300a can thus be sequentially automatically loaded with the tape when the first rotatable tape reel handling apparatus 300a is appropriately disposed with respect to the feeding position 200 and the second rotatable tape reel handling apparatus 300a,b is disposed at the left unloading / waiting zone or position. If the first rotatable tape reel handling apparatus 300a is configured for carrying a first and a second tape reel 110a,b in parallel, the alignment of the first tape reel 110a at the feeding position 200 occurs by way of the shuttle actuator 175, and the subsequent alignment of the second tape reel 110b at the feeding position 200 after the first tape reel 110a is full can occur by way of the shuttle actuator 175 or rotation of the first rotatable tape reel handling apparatus 300a.

Once each tape reel 110 within the first plurality of tape reels 111a is full, the shuttle actuator 175 can simultaneously shift the first and second rotatable multi-reel handling apparatuses 300a,b along the shuttle axis σ until the first rotatable tape reel handling apparatus 300a is disposed at the right unloading / waiting zone or position, which concurrently disposes the second tape reel handling apparatus 300b relative to the feeding position 200 such that the tape reels 110 carried thereby can be automatically sequentially loaded with the tape. If the second rotatable tape reel handling apparatus 300b is configured for carrying a third and a

fourth tape reel 110c,d in parallel, the alignment of the third tape reel 110c at the feeding position 200 occurs by way of the shuttle actuator 175, and the subsequent alignment of the fourth tape reel 110d at the feeding position 200 after the third tape reel 110c is full can occur by way of the shuttle actuator 175 or rotation of the second rotatable tape reel handling apparatus 300b.

While the first rotatable multi-reel handling apparatus 300a is disposed at the right unloading / loading / waiting zone or position and the tape reels 110c,d carried by the second multi-reel handling apparatus 300b are being sequentially loaded with the tape, an operator can manually (a) remove the first tape reel 110a from the first rotatable multi-reel handling apparatus 300a; (b) replace the first tape reel 110a with an empty fifth tape reel (not shown); (c) activate a control element such as a switch coupled to the first rotatable multi-reel handling apparatus 300a, for instance, by way of a foot pedal and/or a button, to rotate the second tape reel 110b to face the operator; and (d) replace the second tape reel 110b with an empty sixth tape reel (not shown).

Once each tape reel 110c,d carried by the second rotatable multi-reel handling apparatus 300b has been loaded with the tape, the shuttle actuator 175 can displace the second rotatable multi-reel handling apparatus 300b to the left unloading / loading / waiting zone or position, which concurrently disposes the first rotatable multi-reel handling apparatus 300a with respect to the feeding position 200 such that the tape reels 110 carried thereby can be sequentially automatically loaded. While the tape reels 110 carried by the first rotatable multi-reel handling apparatus 300a are sequentially being loaded with the tape, an operator can replace the loaded tape reels 110c,d carried by the second rotatable multi-reel handling apparatus 300b with empty tape reels 110 by way of selective rotation of the second rotatable multi-reel handling apparatus 300b in response to operator actuation of a switch, in the manner previously described.

Various other multi-reel rotation and linear shifting configurations are possible in accordance with embodiments of the present disclosure. For instance, in some embodiments, a multi-reel rotation and shuttling apparatus 600 can be configured for selectively shuttling more than two pluralities of tape reels 111a-c along a shuttle axis σ , such as in a manner shown in FIG. 7B.

The multi-reel rotation and shuttling apparatus 600 shown in FIG. 7B can operate in a manner analogous to that described above with reference to FIG. 7A, as will be readily understood by an individual having ordinary skill in the relevant art.

5 Furthermore, in certain embodiments, a multi-reel rotation and shuttling apparatus 700 such as that shown in FIG. 8A can be configured for collectively displacing two or more pluralities of tape reels 111a,b along a vertical shuttle axis σ_v , such as by way of a lift actuator 179 and possibly an associated set of belts, cables, chains, and/or gears, in a manner that will be readily understood by an individual having ordinary skill in the art. Alternatively, in certain
 10 embodiments, a multi-reel rotation and shuttling apparatus 800 such as that shown in FIG. 8B can be configured for selectively displacing two or more pluralities of tape reels 111a,b along multiple horizontal shuttle axes σ_h , σ_h' as well as a vertical shuttle axis σ_v . The embodiment shown in FIG. 8B is configured for shuttling a first plurality of tape reels 111a along a first horizontal shuttle axis σ_h , and a second plurality of tape reels 111b along a second horizontal
 15 shuttle axis σ_h' ; and is further configured for shuttling both the first and second pluralities of tape reels 111a,b along a vertical shuttle axis σ_v (e.g., by way of a lift actuator 179 and possibly an associated set of belts, cables, chains, and/or gears).

Representative Multi-Reel Shuttling Apparatuses

20 FIGs. 9A and 9B are schematic illustrations of representative multi-reel shuttling apparatuses 900 in accordance with particular embodiments of the present disclosure. The embodiment shown in FIG. 9A is configured for collectively displacing a first plurality of tape reels 111a and a second plurality of tape reels 111b along a shuttle axis σ in order to sequentially dispose individual tape reels 110a-d of the first and second pluralities of tape reels 111a,b at
 25 the feeding position. More specifically, a first and a second tape reel 110a,b form the first plurality of tape reels 111a, and a third and a fourth tape reel 110c,d form the second plurality of tape reels 111b. The first and second tape reels 110a,b are carried by a first tape reel support structure 160, and the third and fourth tape reels 110c,d are carried by a second tape reel support structure 160'. The first and second tape reel support structures 160, 160' are
 30 each secured, mounted, or affixed to a plate or platform 178 that is displaceable along the shuttle axis σ by way of a shuttle actuator 175 and possibly a set of gears, wheels, and/or

rollers 177 associated therewith. The shuttle actuator 175 can precisely linearly displace the platform 178 along the shuttle axis to thereby:

5 (a) sequentially precisely position each of the first and second tape reels 110a,b relative to the feeding position 200 such that:

10 (i) the first tape reel 110a is disposed at the feeding position 200 while the second tape reel 110b is disposed at a first standby position (e.g., on the left side of the tape input / output axis) and the second plurality of tape reels 111b is disposed in a first unloading / loading / waiting zone (e.g., on the left side of the tape input / output axis),

after which:

15 (ii) the second tape reel 110b is disposed at the feeding position 200 while the first tape reel 110a is disposed at a second standby position (e.g., on the right side of the tape input / output axis) and the second plurality of tape reels 111b is disposed in the first unloading / loading / waiting zone;

20 and subsequently:

(b) sequentially precisely position each of the third and fourth tape reels 110c,d relative to the feeding position 200 such that:

25 (i) the third tape reel 110c is disposed at the feeding position 200 while the fourth tape reel 110d is disposed at the first standby position (e.g., on the left side of the tape input / output axis) and the first plurality of tape reels 111a is disposed in a second unloading / loading / waiting zone (e.g., on the right side of the tape input / output axis),

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after which:

(ii) the fourth tape reel 110d is disposed at the feeding position 200 while the third tape reel 110c is disposed at the second standby position (e.g., on the right side of the tape input / output axis) and the first plurality of tape reels 111a is disposed in the second unloading / loading / waiting zone.

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An individual having ordinary skill in the relevant art will clearly understand that the multi-reel shuttling apparatus 900 is also configured to operate in a reverse manner with respect to displacement in an opposite direction along the shuttle axis and the sequential performance of tape transfer operations directed to individual tape reels 110 of the first and second pluralities of tape reels 111a,b in manner opposite to that described above.

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Thus, if the first through fourth tape reels 110a-d are initially empty and are intended to be loaded with the tape 12, after the first and second tape reels 110a,b are loaded with the tape 12 and the first plurality of tape reels 111a has been shuttled to the second unloading / loading / waiting zone (e.g., on the right side of the tape input / output axis), while the second plurality of tape reels 111b is disposed at the feeding position 300 and the third tape reel 110c or the fourth tape reel 110d is being loaded with the tape, an operator can remove the fully loaded first and second tape reels 110a,b from the apparatus 900 and respectively replace them with fifth and sixth empty tape reels (not shown). After the third and fourth tape reels 110c,d are loaded with the tape 12, the multi-reel shuttling apparatus 900 can shuttle the third and fourth tape reels 110c,d to the first unloading / loading / waiting zone (e.g., on the left side of the tape input / output axis), thereby simultaneously shuttling the first plurality of tape reels 111a relative to the feeding position such that the fifth tape reel can be loaded with the tape 12 while the sixth tape reel is disposed at the second standby position (e.g., on the right side of the tape input / output axis). While the fifth tape reel is being loaded with the tape 12, the operator can remove one or each of the fully loaded third and fourth tape reels 110c,d from the first tape reel support structure 160, and correspondingly mount one or a pair of empty replacement tape reels 110 on the first tape reel support structure 160. After the fifth tape reel has been loaded with the tape 12, the sixth tape reel is shuttled to the feeding position 200 and the fifth tape reel is simultaneously shuttled to the first standby position (e.g., on the left side of the tape input / output axis). If one or each of the fully loaded third and fourth tape reels 110c,d had not yet been removed from the apparatus 900 and replaced with an empty tape reel while the fifth tape reel was being loaded with the tape 12, one or

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each of the third and fourth tape reels 110c,d can be removed from the apparatus 900 and replaced with an empty tape reel while the fourth tape reel 110d is being loaded with the tape 12.

- 5 The multi-reel shuttling apparatus 900 can perform the foregoing sequence of tape reel loading operations on a repeated, repetitive, cyclical, ongoing, continued, or continual basis by way of sequentially shuttling each tape reel 110 of the first and second pluralities of tape reels 111a,b relative to the feeding position 200 in a first direction and an opposite second direction along the shuttle axis σ , in a manner analogous, generally analogous, or similar to
10 that for other embodiments in accordance with the present disclosure.

FIG. 9B illustrates an embodiment of a multi-reel shuttling apparatuses 900 configured for shuttling three pluralities of tape reels 111a-c along a shuttle axis, where two tape reels 110a,b, 110c,b, 110d,e form each plurality of tape reels 111a-c. The multi-reel shuttling
15 apparatus 900 of FIG. 9B operates in a manner analogous to that described above with respect to the multi-reel shuttling apparatuses 900 of FIG. 9A, as will be readily understood by an individual having ordinary skill in the art in view of the description herein.

Representative Multi-Reel Rotation Apparatus

- 20 FIG. 10 is a schematic illustration of a representative multi-reel rotation apparatus 1000 in accordance with an embodiment of the present disclosure. In an embodiment, the multi-reel rotation apparatus 1000 includes a first and a second rotatable multi-reel handling apparatus 300a,b such as previously described (e.g., with reference to FIGs. 5A – 5E), each of which is respectively configured for carrying a first and a second plurality of tape reels 111a,b. The
25 first plurality of tape reels 111a includes a first and a second tape reel 110a,b; and the second plurality of tape reels 111b includes a third and a fourth tape reel 110c,d. The multi-reel rotation apparatus 100 further includes a master pivot actuator 180 configured for simultaneously or collectively rotating the first and second rotatable multi-reel handling apparatuses 300a,b about or around a master pivot axis P (e.g., on a selectable, selective, or
30 programmable basis) to thereby dispose one of the first and second rotatable multi-reel handling apparatuses 300a,b relative to the feeding position 200 such that the individual tape reels 110a,b, 110c,d can be sequentially loaded with the tape 12, while the other of the first

and second rotatable multi-reel handling apparatuses 300a,b is disposed in an unloading / loading / waiting zone.

5 The master pivot actuator 180 is coupled to a master rotation shaft 182 that corresponds to or defines the master pivot axis P about which simultaneous or collective rotation of the first and second rotatable multi-reel handling apparatuses 300a,b and the first and second pluralities of tape reels 111a,b respectively carried thereby can occur. The master rotation shaft 182 is coupled to an elongate plate or platform 178 for rotationally or rotatably driving the platform about the master pivot axis P . A first and a second counterweight structure 185, 10 185' are pivotally coupled to opposing ends of the platform 178 by way of a first and a second pivot rod 185, 185', respectively; and the first and second rotatable multi-reel handling apparatuses 300a,b are respectively mounted to the first and second counterweight structures 185, 185'. At least a first and a second lock actuator 186, 186' are configured for selectively, selectably, or programmably locking or fixing the first and second counterweight 15 structures 185, 185' in position relative to the first and second pivot rods 185, 185', respectively, such as by way of corresponding first and second lock members, bars, and/or pins 187, 187'.

20 The master pivot actuator 180 can position and maintain the platform 178 in a horizontal orientation to (a) dispose the first plurality of tape reels 111a such that the first tape reel 110a thereof is aligned with the feeding position, and the second tape reel 110b thereof is disposed at a standby position, while concurrently (b) disposing the second plurality of tape reels 111b in an unloading / loading / waiting zone. While the platform 178 is in such a horizontal orientation, the first and second lock members 187, 187' can respectively securely hold the 25 first and second counterweight structures 185, 185' level or in a horizontal orientation. As a result, the first and second pluralities of tape reels 111a,b are securely maintained in position such that the tape reels thereof 110a,b, 110c,d remain in stable spatial positions (e.g., with their flanges 112 oriented vertically). After tape transfer operations directed to the first tape reel 110a are complete, the first rotatable multi-reel handling apparatus 300a can rotate the 30 first plurality of tape reels 111a about a first pivot axis ρ such that the first tape reel 110a rotates away from the feeding position 200 to a standby position, and the second tape reel 110b simultaneously rotates from its standby position toward and to the feeding position 200. During such rotation of the first plurality of tape reels 111a about the first pivot axis ρ , the

second plurality of tape reels 111b remains in the unloading / loading / waiting zone. Once the second tape reel 110b is disposed at the feeding position 200, tape transfer operations directed to the second tape reel 110b can be automatically initiated.

- 5 After tape transfer operations directed to the first and second tape reels 110a,b are complete, the first and second lock actuators 186, 186' can respectively release, retract, or withdraw the first and second lock members 187, 187', and the master pivot actuator 180 can simultaneously rotate the first and second pluralities of tape reels 111a,b across an angle of 180 degrees about the master pivot axis *P* until the physical locations of the first plurality of
10 tape reels 111a and the second plurality of tape reels 111b have been exchanged or swapped. As a result, the second plurality of tape reels 111b is disposed such that the third tape reel 110c is aligned with the feeding position, and the fourth tape reel 110d is disposed at a standby position; and the first plurality of tape reels 111a is concurrently disposed in the unloading / loading / waiting zone. The first and second lock actuators 186, 186' can then
15 activate the lock members 187, 187' to lock or securely hold the first and second rotatable multi-reel handling apparatuses 300a,b level with respect to horizontal. Tape transfer operations directed to the third and fourth tape reels 110c,d can then automatically occur, in a manner essentially identical or analogous to that described above, in association with which the second rotatable multi-reel handling apparatus 300a rotates the second plurality of tape
20 reels 111b about a second pivot axis ρ' to swap the physical locations of the third and fourth tape reels 110c,d with respect to the feeding position 200.

- While tape transfer operations directed to the third and/or fourth tape reels 110c,d carried by the second rotatable multi-reel handling apparatus 300b are occurring, an operator can
25 remove the first and/or second tape reels 110a,b from the first rotatable multi-reel handling apparatus and mount replacement tape reels (not shown) on the first rotatable multi-reel handling apparatus 300b. After the tape transfer operations directed to the third and fourth tape reels 110c,d are complete, the multi-reel rotation apparatus 1000 can again simultaneously rotate the first and second rotatable multi-reel handling apparatuses 300a,b
30 about the master pivot axis *P* in a manner essentially identical to that described above, thereby disposing the first rotatable multi-reel handling apparatus 300a relative to the feeding position such that tape transfer operations directed to the tape reels carried thereby can occur, and simultaneously disposing the second plurality of tape reels 111b at the unloading /

loading / waiting position. During tape transfer operations directed to the tape reels carried by the first rotatable multi-reel handling apparatus 300a, an operator can remove and replace the third and fourth tape reels 110c,d carried by the second rotatable multi-reel handling apparatus 300b, in a manner analogous to that set forth above.

5

Table 1 below indicates non-limiting representative manners in which one or more pluralities of tape reels 111 can be handled by a multi-reel handling apparatus in accordance with particular embodiments of the present disclosure (e.g., one of the representative multi-reel handling apparatuses 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000 considered herein).

10 In general, when a given plurality of tape reels 111 is disposed such that one of its tape reels 110 is in alignment with the feeding position, the physical location of each individual tape reel 110 within this plurality of tape reels 111 can be changed relative to the feeding position and one or more standby positions corresponding to the feeding position by way of rotation or shuttling, depending upon embodiment details and/or the total number of tape reels 110 that the plurality of tape reels 111 includes. Furthermore, an embodiment configured for handling multiple pluralities of tape reels 111 can be configured for concurrently shuttling or rotating the multiple pluralities of tape reels 111 in order to transport one plurality of tape reels 111a away from the feeding position (e.g., toward or to an unloading / loading / waiting zone) and another plurality of tape reels 111 toward the feeding position.

20

# of Pluralities of Reels	# of Reels in Each Plurality of Reels	Within a Plurality of Reels, Reel Transfer to Feeding Position / Standby Position	Simultaneous Displacement of Multiple Pluralities of Reels
1	2	Rotation or Shuttle	N/A
1	4	Rotation	N/A
2	2	Rotation or Shuttle	Shuttle or Rotation
3	2	Rotation or Shuttle	Shuttle or Rotation
2	4	Rotation	Shuttle or Rotation

Table 1.

25 Taken together, the third and fourth columns of Table 1 indicate or define multiple possible tape reel and tape reel plurality handling permutations and/or combinations for automatically performing tape transfer operations directed to one or more pluralities of tape reels 111 as

indicated by the first column of Table 1, where a selected number of pluralities of tape reels 111 can carry up to the number of individual tape reels 110 indicated by the second column of Table 1. The numbers shown in Table 1 are representative and are not intended to be limiting, as a multi-reel handling apparatus in accordance with an embodiment of the present disclosure can be configured for handling more than three pluralities of tape reels 111 and/or a different number of individual tape reels 110 than indicated in Table 1.

Throughput Considerations

By way of a multi-reel handling apparatus (e.g., any of the representative multi-reel handling apparatuses 100, 300, 400, 500, 600, 700, 800, 900, 1000 considered herein) configured to operate with a tape and reel machine 10 in accordance with an embodiment of the present disclosure, a sequence of tape transfer operations can occur on a repeated / cyclical / ongoing or continual / continuous basis for multiple tape reels 110 (e.g., across two, ten, twenty, fifty, one hundred, several hundred, or more tape reels 110) without delaying or interrupting the initiation or performance of each tape transfer operation within the sequence of tape transfer operations, thus enhancing or maximizing tape and reel machine throughput. In environments in which each of several or many tape and reel machines 10 is equipped with a multi-reel handling apparatus in accordance with an embodiment of the present disclosure, a significantly greater number of concurrent or parallel sequences of tape transfer operations across the multiple tape and reel machines 10 can be managed by a single operator compared to environments in which tape and reel machines 10 are equipped with conventional tape reel handling apparatuses. In general, an amount of extra or additional time that a single operator has available to simultaneously manage multiple tape and reel machines 10 when the tape and reel machines 10 are configured to operate with a multi-reel handling apparatus in accordance with an embodiment of the present disclosure is correlated with or is a function of the time required for the completion of tape reel loading or unloading operations directed to a single tape reel, multiplied by one less than the number of tape reels that the multi-reel handling apparatus is configured for handling.

System Size / Footprint Considerations

As indicated in FIGs. 1B – 1C and elsewhere, a multi-reel handling apparatus in accordance with the present disclosure (e.g., at least some or each of the representative multi-reel handling apparatuses 100, 300, 400, 500, 600, 700, 800, 900, 1000 considered herein) does

not require that an overall tape and reel system in accordance with an embodiment of the present disclosure, which includes the tape and reel machine 10 and a multi-reel handling apparatus in accordance with an embodiment of the present disclosure configured to operate therewith, have a greater depth in a direction parallel to the tape input . output axis (e.g., as measured along the x axis) than a conventional tape and reel system in which a tape and reel machine 10 is configured to operate with a conventional tape reel handling apparatus (e.g., a single arm disposed at a predetermined position away from the tape and reel machine 10, and which supports a single tape reel 110). In addition, in various embodiments a multi-reel handling apparatus in accordance with an embodiment of the present disclosure (e.g., at least some of the representative embodiments 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000 considered herein) does not or need not significantly increase the overall width of a tape and reel system (e.g., as measured along the y axis). A multi-reel handling apparatus in accordance with the present disclosure thus provides a space efficient and mechanically simple, reliable, and robust apparatus that can significantly or greatly enhance or maximize the throughput of component taping and de-taping operations.

Aspects of particular embodiments of the present disclosure address at least one aspect, problem, limitation, and/or disadvantage associated with existing manners of handling, loading and/or unloading tape reels in association with tape and reel machine operation. While features, aspects, and/or advantages associated with certain embodiments have been described in the disclosure, other embodiments may also exhibit such features, aspects, and/or advantages, and not all embodiments need necessarily exhibit such features, aspects, and/or advantages to fall within the scope of the present disclosure. One or more portions of the above-disclosed systems, apparatuses, devices, components, processes, or alternatives thereof may be desirably combined into other different systems, apparatuses, devices, components, processes, and/or applications while remaining within the scope of the present disclosure. In addition, various modifications, alterations, and/or improvements may be made to various embodiments that are disclosed herein, while remaining within the scope of the present disclosure.

Claims

1. A method for handling a plurality of tape reels using a multi-reel handling apparatus configured for operation with a tape and reel machine, the tape and reel machine configured for displacing a flexible tape carrying components along a tape transport axis to transfer the tape and the components carried thereby between the tape and reel machine and a tape reel disposed at a feeding position common to the plurality of tape reels, the method comprising:

disposing a first tape reel having a first winding axis at the feeding position;

disposing a second tape reel having a second winding axis at a first standby position

within a set of standby positions, wherein each standby position is offset from the tape transport axis;

spinning the first tape reel about the first winding axis while transferring the tape between the tape and reel machine and the first tape reel;

automatically determining whether transfer of the tape between the tape and reel machine and the first tape reel is complete; and

performing a set of tape reel swap operations after transfer of the tape between the tape and reel machine and the first tape reel is complete, the set of tape reel swap operations comprising simultaneously displacing the first and second tape reels by (a) linearly shuttling the first and second tape reels in a common direction perpendicular to the tape transport axis, or (b) changing the physical locations of the first and second tape reels by rotating the first and second tape reels about a common pivot axis that is perpendicular to the first and second winding axes to thereby (i) dispose the second tape reel at the feeding position, and (ii) dispose the first tape reel at a second standby position within the set of standby positions.

2. The method of claim 1, wherein the first and second winding axes are coincident with each other when the second tape reel is disposed at the feeding position.

3. The method of claim 1, wherein the first standby position and the second standby position comprise the same physical location or different physical locations in space.

4. The method of claim 1, wherein simultaneously linearly shuttling the first and second tape reels comprises horizontally shuttling the first and second tape reels in a direction parallel to at least one of the first and second winding axes.
- 5 5. The method of claim 4, wherein the first standby position and the second standby position are on opposite sides of the tape transport axis.
6. The method of claim 1, wherein changing the physical locations of the first and second tape reels by simultaneously rotating the first and second tape reels about the pivot axis
10 comprises rotating the first and second tape reels such that the first and second winding axes circumferentially travel in an arc around the pivot axis within a plane that is perpendicular to the pivot axis.
7. The method of claim 6, wherein the first standby position and the second standby
15 positions are on the same side of the tape transport axis.
8. The method of claim 6 or 7, wherein the pivot axis is parallel or perpendicular to the tape transport axis.
- 20 9. The method of any one of claims 1 – 6, further comprising:
spinning the second tape reel about the second winding axis; and
automatically initiating transfer of the tape between the tape and reel machine and the
second tape reel while the first tape reel is disposed at the second standby position.
- 25 10. The method of claim 9, further comprising removing the first tape reel from the multi-reel handling apparatus and replacing it with a third tape reel while the second tape reel is disposed at the feeding position and the tape is being transferred between the tape and reel machine and the second tape reel.
- 30 11. The method of claim 10, wherein removing the first tape reel from the multi-reel handling apparatus and replacing it with the third tape reel occurs without delaying or interrupting the transfer of the tape between the tape and reel machine and the second tape reel.

12. The method of any of claims 1 - 6, further comprising removing a plurality of tape reels from the multi-reel handling apparatus and replacing each of the plurality of removed tape reels with another tape reel on the multi-reel handling apparatus while the second tape reel is disposed at the feeding position and the tape is being transferred between the tape and reel machine and the second tape reel.

13. The method of any one of claims 1 – 6, wherein simultaneously displacing the first and second tape reels comprises activating a tape reel swap actuator to linearly or rotationally displace a support structure that carries the first and second tape reels.

14. The method of any one of claims 1 – 6, further comprising spinning the first tape reel about the first winding axis using a first winding actuator when the first tape reel is disposed at the feeding position, and spinning the second tape reel about the second winding axis using a second winding actuator distinct from the first winding actuator when the second tape reel is disposed at the feeding position.

15. The method of claim 1, wherein the plurality of tape reels includes a first plurality of tape reels comprising the first and second tape reels, and a second plurality of tape reels comprising a third tape reel and a fourth tape reel respectively having a third winding axis and a fourth winding axis, and wherein the method further comprises:

simultaneously linearly shuttling the first through fourth tape reels in a common direction perpendicular to the tape transport axis to thereby simultaneously (iii) dispose the first and second tape reels in an unloading zone in which at least one of the first and second tape reels is removable from the multi-reel handling apparatus, and (iv) dispose the third tape reel at the feeding position while disposing the fourth tape reel at a standby position within the set of standby positions; and

simultaneously displacing the third and fourth tape reels relative to the feeding position while the first and second tape reels remain in the unloading zone by (a) linearly shuttling the first through fourth tape reels in a common direction perpendicular to the tape transport axis, or (b) changing the physical locations of the third and fourth tape reels by rotating the third and fourth tape reels about a common pivot axis that is perpendicular to the third and fourth winding axes to thereby (i) dispose the fourth

tape reel at the feeding position, and (ii) dispose the third tape reel at a standby position within the set of standby positions.

16. The method of claim 15, further comprising removing each of the first tape reel and the second tape reel from the multi-reel handling apparatus and replacing the first tape reel with a fifth tape reel and the second tape reel with a sixth tape reel without delaying or interrupting the transfer of the tape between the tape and reel machine and at least one of the third tape reel and the fourth tape reel.

17. The method of claim 15, wherein the plurality of tape reels includes a third plurality of tape reels comprising a fifth tape reel and a sixth tape reel respectively having a fifth winding axis and a sixth winding axis, and wherein the set of tape reel swap operations further comprises:

simultaneously linearly shuttling the first through sixth tape reels in a common direction perpendicular to the tape transport axis to thereby simultaneously (iii) dispose the first through fourth tape reels in the unloading zone at which at least one of the first through fourth tape reels is removable from the multi-reel handling apparatus, and (iv) dispose the fifth tape reel at the feeding position while disposing the sixth tape reel at a standby position within the set of standby positions; and

simultaneously displacing the fifth and sixth tape reels relative to the feeding position while the first through fourth tape reels remain in the unloading zone by (a) linearly shuttling the first through sixth tape reels in a common direction perpendicular to the tape transport axis, or (b) changing the physical locations of the fifth and sixth tape reels by rotating the fifth and sixth tape reels about a common pivot axis that is perpendicular to the fifth and sixth winding axes to thereby (i) dispose the sixth tape reel at the feeding position, and (ii) dispose the fifth tape reel at a standby position within the set of standby positions.

18. A multi-reel handling apparatus configured for collectively displacing a plurality of tape reels relative to a common feeding position of a tape and reel machine at which a flexible tape carrying components is displaceable along a tape transport axis for transfer between the tape and reel machine and one of the plurality of tape reels that is disposed at the feeding position, the apparatus comprising:

- a set of tape reel support structures, each tape reel support structure configured for carrying a plurality of tape reels and providing a plurality of tape reel holding mechanisms, each of the plurality of tape reel holding mechanisms comprising a shaft configured for carrying a tape reel such that the tape reel is spinnable about a winding axis parallel to the shaft;
- a set of multi-reel displacement actuators comprising:
- (a) an actuator configured for linearly shuttling each tape reel support structure and the tape reel holding mechanisms carried thereby in a direction perpendicular to the tape transport axis, and/or
 - (b) an actuator configured for changing the physical locations of the tape reel holding mechanisms carried by a selected tape reel support structure by rotating the selected tape reel support structure about a pivot axis that is perpendicular to the shaft of each of the tape reel holding mechanisms carried thereby,
- wherein the set of multi-reel displacement actuators is configured for selectively (i) disposing a particular tape reel holding mechanism of the plurality of tape reel holding mechanisms and the shaft thereof in alignment with the feeding position such that the shaft extends through a plane containing the tape transport axis and can carry a tape reel to or from which the tape can be automatically transferred, and (ii) disposing each other tape reel holding mechanism of the plurality of tape reel holding mechanisms out of alignment with the feeding position at a standby position within a set of standby positions corresponding to the feeding position or in an unloading zone; and
- a set of winding actuators configured for selectively spinning the shaft of a tape reel holding mechanism when the tape reel holding mechanism is disposed in alignment with the feeding position.

19. The multi-reel handling apparatus of claim 18, wherein the plurality of tape reel holding mechanisms includes a first tape reel holding mechanism having a first shaft and a second tape reel holding mechanism having a second shaft, and wherein the first and second shafts are parallel to each other when the first tape reel holding mechanism or the second tape reel holding mechanism is in alignment with the feeding position.

20. The multi-reel handling apparatus of claim 18, wherein the set of multi-reel displacement actuators is configured for concurrently linearly shuttling at least two tape reel support structures in a direction parallel to at least a first shaft of a first tape reel holding mechanism and a second shaft of a tape reel holding mechanism carried by each of the at least two tape
5 reel support structures.

21. The multi-reel handling apparatus of claim 18, wherein the set of multi-reel displacement actuators is configured for disposing (a) a first shaft of a first tape reel holding mechanism in alignment with the feeding position while a second shaft of the first tape reel holding
10 mechanism is disposed on a first side of the tape transport axis, and (b) the second shaft of the first tape reel holding mechanism in alignment with the feeding position while the first shaft of the first tape reel holding mechanism is disposed on a second side of the tape transport axis opposite to the first side of the tape transport axis.

22. The multi-reel handling apparatus of claim 18, wherein the set of multi-reel displacement actuators is configured for disposing (a) a first shaft of a first tape reel holding mechanism in alignment with the feeding position while a second shaft of the first tape reel holding
15 mechanism is disposed on a first side of the tape transport axis, and (b) the second shaft of the first tape reel holding mechanism in alignment with the feeding position while the first shaft of the first tape reel holding mechanism is disposed on the first side of the tape transport axis.
20

23. The multi-reel handling apparatus of claim 21 or 22, wherein the set of multi-reel displacement actuators is further configured for disposing a second tape reel support structure and a plurality of tape reel holding mechanisms carried thereby in the unloading zone while
25 the first shaft or the second shaft carried by the first tape reel holding structure is disposed in alignment with the feeding position.

24. The multi-reel handling apparatus of claim 21 or 22, wherein the set of multi-reel displacement actuators is further configured for disposing a second tape reel support structure and the plurality of tape reel holding mechanisms carried thereby on a first side of the tape
30 transport axis and disposing a third tape reel support structure and a plurality of tape reel holding mechanisms carried thereby on a second side of the tape transport axis opposite to

the first side of the tape transport axis while the first shaft or the second shaft carried by the first tape reel holding structure is disposed in alignment with the feeding position.

25. The multi-reel handling apparatus of claim 18, wherein the pivot axis is parallel to the
5 tape transport axis or perpendicular to the tape transport axis.

26. The multi-reel handling apparatus of claim 18, wherein the set of multi-reel displacement
actuators is configured for collective precise linear shuttling of each of a plurality of tape reel
support structures in a direction perpendicular to the tape transport axis toward, to, and past
10 the feeding position to selectively sequentially dispose the shaft of each tape reel holding
mechanism of each of the plurality of tape reel support structures in alignment with the
feeding position.

27. The multi-reel handling apparatus of claim 18, wherein the set of multi-reel displacement
15 actuators is configured for (a) collective precise linear shuttling of each of a plurality of tape
reel support structures in a direction perpendicular to the tape transport axis toward, to, and
past the feeding position to selectively dispose the shaft of a first tape reel holding
mechanism of each of the plurality of tape reel support structures in alignment with the
feeding position, and (b) for each tape reel support structure, collective precise rotation of the
20 tape reel support structure about a pivot axis corresponding thereto when a shaft carried by
the tape reel support structure is disposed in alignment with the feeding position.

28. The multi-reel handling apparatus of claim 18, wherein the set of winding actuators
comprises a first spin actuator and a distinct second spin actuator corresponding to each tape
25 reel support structure, and wherein the first and second spin actuators corresponding to a
given tape reel support structure are respectively configured for spinning a first shaft and a
second shaft carried by the tape reel support structure.