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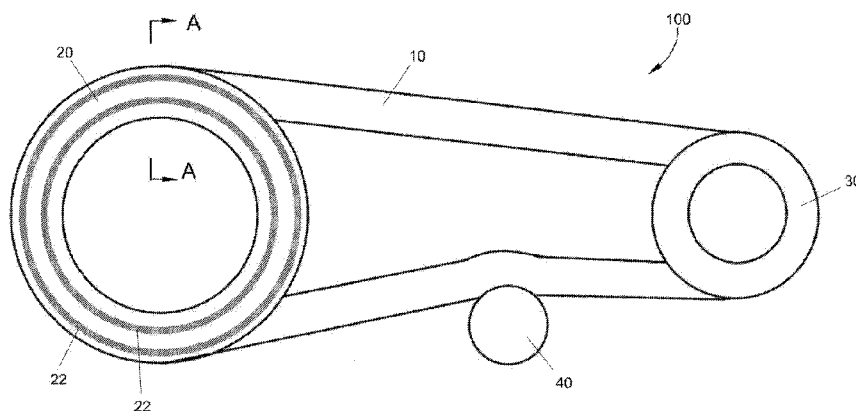


FIG. 5

(57) Abstract: A system and method capable of detecting damage in a belt before catastrophic failure of the belt occurs. The system includes a belt having at least a first conductive component and/or at least a first dielectric component, and one or more pulleys to which the belt is mounted. At least a first of the pulleys has at least one conductive component that, in combination with the first conductive component or the first dielectric component of the belt, defines an electrical element. At least a portion of the electrical element is located within the belt so as to be physically responsive to transitory and permanent distortions of the belt resulting from extrinsic and/or intrinsic sources. Electrical potential is applied through the electrical element so as to generate an electrical signal from the electrical element corresponding to a physical response of the belt to a transitory and/or permanent distortion.

BELT AND PULLEY SYSTEMS AND METHODS OF DETECTING BELT DAMAGE

BACKGROUND OF THE INVENTION

[0001] The present invention generally relates to belts of types used to convey or transmit motion, power and/or objects. The invention particularly relates belt and pulley systems and methods for detecting wear or damage to a belt prior to failure thereof.

[0002] Belt and pulley systems are used in many applications to convey or transmit motion, power and/or objects. As used herein, a belt and pulley system will be understood to comprise one or more belts interconnected by two or more pulleys, with the term “belt” understood to encompass a wide variety of flexible belts and the term “pulley” understood to encompass a wide variety of pulleys, sheaves, wheels, etc. The failure of a belt may have a much greater impact than simply downtime to stop machinery to replace the belt. Many applications that require the use of belts are in industries that can suffer serious setbacks in the event of a catastrophic belt failure, and would therefore benefit from the use of a technology to detect damage to a belt before catastrophic failure occurs.

[0003] Current technologies for belt monitoring typically examine conditions that are known to cause damage to a belt. For example, systems exist for monitoring the alignment of a belt during its operation. There are other systems adapted to monitor the tension of a belt or monitor slippage between a belt and the pulley system on which the belt operates. Still other technologies exist that are capable of collecting and analyzing visual data to determine if a belt has suffered damage. There are also belt monitoring products that monitor conditions within a belt. One such product utilizes lateral rip sensors that are built into a belt and are monitored

as the sensors pass over a sensor. Systems also exist that are capable of monitoring steel cords within a belt as the cords pass over a sensor.

[0004] Despite the existence of the above-noted technologies, there is an ongoing desire for systems and methods capable of detecting damage, abnormalities, etc., in a belt, preferably before catastrophic failure of the belt occurs.

BRIEF DESCRIPTION OF THE INVENTION

[0005] The present invention provides systems and methods capable of detecting damage, abnormalities, etc., in belts adapted to convey or transmit motion, power and/or objects, and preferably to detect damage, abnormalities, etc., before catastrophic belt failure occurs.

[0006] According to one aspect of the invention, a belt and pulley system is provided that has an integral life-sensing capability. The system includes a belt having at least a first conductive component and/or at least a first dielectric component, and one or more pulleys to which the belt is mounted. At least a first of the one or more pulleys has at least one conductive component that, in combination with the first conductive component or the first dielectric component of the belt, defines an electrical element chosen from the group consisting of capacitive and resistive elements. At least a portion of the electrical element is located within the belt so as to be physically responsive to transitory and permanent distortions of the belt resulting from extrinsic and/or intrinsic sources. The system is configured to apply an electrical potential through the electrical element so as to generate an electrical signal from the electrical element corresponding to a physical response of the belt to a transitory and/or permanent distortion.

[0007] According to another aspect of the invention, a method of sensing the life of a belt mounted to one or more pulleys includes providing the belt to have at least a first conductive component and/or at least a first dielectric component, and providing at least a first of the one or more pulleys to have at least one conductive component that, in combination with the first conductive component or the first dielectric component of the belt, defines an electrical element chosen from the group consisting of capacitive and resistive elements, wherein at least a portion of the electrical element is located within the belt so as to be physically responsive to transitory and permanent distortions of the belt resulting from extrinsic and/or intrinsic sources. The method further includes applying an electrical potential with at least the first pulley and through the electrical element so as to generate an electrical signal from the electrical element corresponding to a physical response of the belt to a transitory and/or permanent distortion.

[0008] Technical effects of the method and system described above preferably include the ability to detect impending belt failure and provide warnings in order to avoid catastrophic belt failures that might otherwise interfere with or halt productivity in a variety of applications and industries.

[0009] Other aspects and advantages of this invention will be better appreciated from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 schematically represents a cross-sectional view of a nonlimiting belt comprising a dielectric material suitable for use in systems in accordance with certain aspects of the present invention.

[0011] FIG. 2 schematically represents a cross-sectional view of another nonlimiting belt comprising a conductive material suitable for use in systems in accordance with certain aspects of the present invention.

[0012] FIGS. 3 and 4 schematically represent cross-sectional views of two nonlimiting belts comprising both dielectric and conductive materials suitable for use in systems in accordance with certain aspects of the present invention.

[0013] FIG. 5 schematically represents a nonlimiting pulley system suitable for detecting capacitance, resistance, inductance, or a combination thereof in cooperation with a belt in accordance with certain aspects of the present invention.

[0014] FIG. 6 schematically represents a cross-sectional view taken along line A-A of FIG. 5 and shows the belt engaged with one of the pulleys.

[0015] FIG. 7 schematically represents another nonlimiting pulley system suitable for detecting capacitance, resistance, inductance, or a combination thereof in cooperation with a belt in accordance with certain aspects of the present invention.

[0016] FIG. 8 schematically represents cross-sectional views taken along lines B-B and C-C of FIG. 7 and shows the belt engaged with two of the pulleys.

[0017] FIG. 9 schematically represents another nonlimiting pulley system suitable for detecting capacitance, resistance, inductance, or a combination thereof in cooperation with a belt in accordance with certain aspects of the present invention.

[0018] FIG. 10 schematically represents cross-sectional views taken along lines D-D and E-E of FIG. 9 and shows the belt engaged with two of the pulleys.

[0019] FIG. 11 schematically represents another nonlimiting pulley system suitable for detecting capacitance, resistance, inductance, or a combination thereof in cooperation with a belt in accordance with certain aspects of the present invention.

[0020] FIG. 12 schematically represents cross-sectional views taken along lines F-F and G-G of FIG. 11 and shows the belt engaged with two of the pulleys.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Pulley systems and methods disclosed herein use capacitance, resistance, inductance, or a combination thereof whose detected values can be used to determine a physical condition of a belt, for example, belt stretch, tension, partial failure, etc. As an example, a belt can be configured to exhibit a capacitance that changes when the belt has been damaged due to changes that occur in the dielectric constant of the belt material, in the thickness of a dielectric layer within the belt, or in the interfaces between different materials within the belt. Many different types of damage from various extrinsic and intrinsic sources can affect these factors, for example, permanent distortions such as cracking, layer separation, and burning, as well as transitory distortions that over time will result in permanent distortions. If such a change is detected, a user can be alerted that the belt's integrity has been compromised and should be replaced. For convenience, consistent reference numbers are used throughout the drawings to identify the same or functionally equivalent elements.

[0022] According to a preferred aspect of the invention, one or more pulleys (which includes sheaves, wheels, etc.) of a pulley system can be configured and utilized to assist in the detection of a change in capacitance, resistance, and/or inductance of a belt. With the application of a suitable electrical potential, such a pulley system enables a change in capacitance, resistance, and/or inductance to be detected and generate a signal that can be interpreted by to a data acquisition device that monitors the signal. The pulley may be configured to impede the signal everywhere except where the signal is transferred. The data acquisition device can then be used to receive the signal and, based on characteristics of the signal, detect and/or identify a change in capacitance, resistance, and/or inductance as an indicator of an impending failure of the belt, in which case the data acquisition device may be adapted to provide a warning to a user or system prior to an actual failure of the belt occurring.

[0023] FIGS. 1 through 4 represent nonlimiting embodiments of belts 10a, 10b, 10c, and 10d of types that can be employed with pulley systems encompassing certain aspects of the invention, and FIGS. 5 through 12 schematically represent nonlimiting embodiments of pulley systems 100, 200, 300 and 400 comprising pulleys (sheaves) 20, 30, 40 and 50 on which one or more of the belts 10a, 10b, 10c, and 10d (collectively identified with reference number 10 in FIGS. 5 through 12) can be installed. The belts 10a, 10b, 10c, and 10d are schematically represented in FIGS. 1 through 4 and the pulley systems 100, 200, 300 and 400 are schematically represented in FIGS. 5 through 12 for the purpose of describing certain aspects of the invention, and therefore it should be understood that various other belt and pulley system configurations are also within the scope of the invention, and such belts and pulley systems can be configured for use in a variety of applications, for example, to convey or transmit motion, power and/or objects. In each case, the belt 10 and one or more of its associated pulleys 20, 30, 40 and

50 define an electric circuit/element that utilizes dielectric and/or conductive components within the belt 10 and conductive components of the associated pulley(s) 20, 30, 40 and/or 50. The pulley(s) 20, 30, 40 and/or 50 is/are adapted to apply an electric potential to the belt 10 by which changes in capacitance, resistance, and/or inductance of the electric circuit can be sensed, indicative of the physical condition of the belt 10. It is foreseeable and within the scope of the invention that the electrical potential may be applied by a component other than one of the pulley(s) 20, 30, 40, and/or 50. In combination, the belts 10 and their associated pulley(s) 20, 30, 40 and/or 50 are preferably capable of use in a monitoring system that is able to electronically detect a defect in the belt 10 due to cord failure, layer separation, surface damage, etc. Typically of particular interest will be the tension cord region of a belt, which on belts of the types depicted (V-belts having trapezoidal cross-section shapes) will come into contact with a pulley on which the belt is installed.

[0024] In the schematic cross-sectional representations of FIGS. 1 through 4, lighter-shaded portions of the belts 10a, 10c and 10d represent a dielectric material (a nonlimiting example being rubber), and darker-shaded portions of the belts 10b, 10c and 10d represent a conductive material (a nonlimiting example being conductive rubber). It is within the scope of the invention that the belts 10a, 10b, 10c and 10d may comprise any number of additional conductive, dielectric, reinforcement, or other materials and components.

[0025] FIG. 1 represents a fully dielectric belt 10a, e.g., formed entirely of a dielectric material or at least exhibiting dielectric properties throughout its cross-sectional area. The entire belt 10a defines a dielectric layer 12 that can be employed as a component (electrode) of a capacitor whose capacitance changes due to internal or external damage to the belt 10a. FIG. 2 represents a fully

conductive belt 10b, e.g., formed entirely of an electrically conductive material or at least exhibiting electrically conductive properties throughout its cross-sectional area. The entire belt 10b defines a conductor layer 14 as a component of the belt 10b whose electrical resistance changes due to internal or external damage to the belt 10b.

[0026] FIG. 3 represents a composite belt 10c having top and bottom conductive layers 14 formed of one or more conductive materials, and a dielectric layer 12 therebetween that is formed of one or more dielectric material and located within a tension cord region of the belt 10c. The dielectric and conductive layers 12 and 14 can be employed as components (electrodes) of a fully integrated capacitor whose capacitance changes due to internal or external damage to the belt 10c, primarily within the dielectric tension cord region of the belt 10c as a result of changes occurring in the dielectric layer 12 that alter its dielectric properties.

[0027] FIG. 4 represents a composite belt 10d having top and bottom dielectric layers 12 of one or more dielectric materials, and a conductive layer 14 therebetween that is formed of one or more conductive materials and located within a tension cord region of the belt 10d. The dielectric and conductive layers 12 and 14 can be employed as components (electrodes) of a capacitor. In this embodiment, the conductive layer 14 can serve as a conductive electrode of the capacitor, and a pulley can be employed to define at least one additional conductive electrode to complete a capacitor whose capacitance changes due to internal or external damage to the belt 10d, primarily within the top and/or bottom dielectric layers 12 of the belt 10d.

[0028] The nonlimiting pulley system 100 of FIGS. 5 and 6 is schematically represented as comprising three pulleys 20, 30 and 40, one of which serves as an

idler pulley 40. The pulley 20 is schematically represented as having conductors 22 formed of a conductive material (e.g., copper) on opposing interior walls 24 of a groove thereof that are in contact with the belt 10 during operation. By utilizing any suitable means capable of applying an electrical potential across the conductors 22 of the pulley 20, an electrical signal can be generated with the electrical element (e.g., capacitor, resistor, inductor) defined by the material(s) of the belt 10 and the conductors 22 on the pulley 20, with such a signal being capable of being processed and interpreted by a suitable data acquisition device to indicate a physical response of the belt 10 to a transitory and/or permanent distortion. In the embodiment represented in FIGS. 5 and 6, signal values (capacitance, resistance, inductance, or a combination thereof) may be detected laterally across the width of the belt 10, through a depth of the belt 10, or a combination thereof between the opposing interior walls 24 of the pulley 20. As shown, the values can be detected from an upper portion on one lateral side of the belt 10 (adjacent one of the conductors 22) to a lower portion on the opposite lateral side of the belt 10 (adjacent the other conductor 22), as represented in FIG. 6. The system 100 is particularly adapted, but not limited to, use in combination with the fully dielectric belt 10a of FIG. 1, the fully conductive belt 10b of FIG. 2, the composite belt 10c of FIG. 3 having top and bottom conductive layers 14 and the dielectric layer 12 therebetween, and the composite belt 10d of FIG. 4 having top and bottom dielectric layers 12 and the conductive layer 14 therebetween.

[0029] The nonlimiting pulley system 200 of FIGS. 7 and 8 is also schematically represented as comprising three pulleys 20, 30 and 40, one of which serves as an idler pulley 40. In FIGS. 7 and 8, two of the pulleys 20 and 30 are schematically represented as having conductors 22 formed of a conductive material. In contrast to FIGS. 5 and 6, each pulley 20 and 30 may have a single conductor 22 on one of its interior walls 24, wherein the conductors 22 are located to contact a different

lateral side of the belt 10 during operation. With the application of an electrical potential across the conductors 22 of the different pulleys 20 and 30, signal values (capacitance, resistance, inductance, or a combination thereof) may be detected simultaneously laterally through the cross-section (width) of the belt 10 and also along the length of the belt 10 between the pulleys 20 and 30. In the configuration shown, signal values can be detected between an upper portion on one lateral side of the belt 10 that contacts the conductor 22 of the pulley 20, and a lower portion on the opposite lateral side of the belt 10 that contacts the conductor 22 of the pulley 30, as evident from FIG. 8. The system 200 is particularly adapted, but not limited to, use in combination with the fully dielectric belt 10a of FIG. 1, the fully conductive belt 10b of FIG. 2, the composite belt 10c of FIG. 3 having top and bottom conductive layers 14 and the dielectric layer 12 therebetween, and the composite belt 10d of FIG. 4 having top and bottom dielectric layers 12 and the conductive layer 14 therebetween.

[0030] The nonlimiting pulley system 300 of FIGS. 9 and 10 is similar to that of FIGS. 5 through 8, in that the system 300 is schematically represented as comprising two pulleys 20 and 30 and an idler pulley 40. In FIGS. 9 and 10, the pulley 30 is schematically represented as having a conductor 22 formed of a conductive material on one of its interior walls 24, and the idler pulley 40 is schematically represented as having a conductor 22 formed of a conductive material on its surface that contacts the wider nonlateral side of the belt 10, such that each conductor 22 contacts a different surface (at a lateral side or a nonlateral side) of the belt 10 during operation. With the application of an electrical potential across the conductors 22 of the different pulleys 30 and 40, signal values (capacitance, resistance, inductance, or a combination thereof) may be detected along the length of the belt 10 between the idler pulley 40 and the pulley 30 and diagonally through the belt 10 between its wider nonlateral side and one of its

lateral sides, preferably in a region of the lateral side remote from the wider nonlateral side of the belt 10 contacted by the idler pulley 40 as represented in FIG. 10. As represented in FIGS. 9 and 10, the system 300 is particularly adapted for use in combination with the belts 10a and 10b represented in FIGS. 1 and 2, though it should be appreciated that the system 300 could be used in combination with any of the belts 10a, 10b, 10c and 10 represented in FIGS. 1 through 4 by appropriately locating the conductor 22 on the pulley 30.

[0031] The nonlimiting pulley system 400 of FIGS. 11 and 12 is schematically represented as comprising two pulleys 20 and 30 and two idler pulleys 40 and 50, with each idler pulley 40 and 50 having a conductor 22 on an exterior surface thereof. The conductors 22 of the idler pulleys 40 and 50 contact the wider and narrower nonlateral sides, respectively, of the belt 10, such that the conductors 22 contact two oppositely-disposed surfaces of the belt 10 during operation. With the application of an electrical potential across the conductors 22 of the different pulleys 40 and 50, signal values (capacitance, resistance, inductance, or a combination thereof) may be detected through the thickness (height) of the belt 10 between its wider and narrower nonlateral sides, and along the length of the belt 10 between the pair of idler pulleys 40 and 50, as represented in FIG. 12. This system 400 is particularly adapted for, but not limited to, use in combination with the fully dielectric belt 10a or the fully conductive belt 10b, such as the types represented in FIGS. 1 and 2, though it should be appreciated that the system 400 could be adapted for use with any of the belts 10a, 10b, 10c and 10 represented in FIGS. 1 through 4.

[0032] Systems of the types described above can be employed in the operation of conveyor and power transmission equipment to warn of an impending belt failure with enough advance notice to safely shut down the equipment prior to belt failure. Such a system may also be adapted to collect temporal data regarding the physical

condition of the belt for future management, planning, and technological development purposes.

[0033] In view of the above, systems utilizing belts and pulleys of the types described above can be utilized to avoid catastrophic belt failures that might otherwise halt productivity in a range of applications and industries. In particular, such a system preferably serves to monitor belts and allow for their removal when damaged but before catastrophic failure. Belts of the types described herein can also be advantageous to belt manufacturers in terms of being able to monitor quality control. For example, a belt can undergo a quality check before leaving the factory, reducing the risk that the belt manufacturer will ultimately be held responsible for damages that may be a consequence of a belt having a defect that is difficult to detect.

[0034] While prior art approaches for monitoring belts for misalignment and incorrect tensioning can help avoid damage to a belt, such approaches do not enable the monitoring of the belt itself for the detection of damage or the prediction of when the belt needs to be replaced. Similarly, the ability to monitor belt slippage does not detect actual damage to a belt, but simply provides an indication that the belt needs to be re-tensioned. In contrast, systems equipped with belts and pulleys as described above are capable of providing the capability to monitor tension (through transitory distortions associated therewithin) and damage (permanent distortions) simultaneously. Collecting visual data of the exterior of a belt cannot provide an indication as to whether an internal issue within the belt may cause the belt to fail, whereas the belts and pulleys described above are specifically intended to detect internal damage and flaws that cannot be seen from the exterior of the belt. Lastly, systems utilizing the belts and pulleys described above are capable of monitoring the entire length of a belt during its operation, and allow for the use of

detection and data acquisition means that can be relatively inexpensive.

[0035] The invention is not limited to the systems and pulleys illustrated and described herein. It is foreseeable and within the scope of the invention that a system could have any number of pulleys or other structural features in contact with a belt that are configured to electrically detect changes in capacitance, resistance, inductance, or a combination thereof through at least a portion of the belt in order to identify wear or damage to the belt. Furthermore, belts, pulleys, etc., could be used that differ from those shown, such as conveyer belts, serpentine belts, and various types of pulleys and pulley systems. In addition, pulleys, belts, conductors, etc., may be formed of any material suitable for achieving their respective functional purposes, including their desired electrically conductive or dielectric properties.

[0036] Therefore, while the invention has been described in terms of specific embodiments, it is apparent that other forms could be adopted by one skilled in the art, and the scope of the invention is to be limited only by the following claims.

CLAIMS:

1. A belt and pulley system (100,200,300,400) having an integral life-sensing capability, the system (100,200,300,400) comprising:

a belt (10) having at least a first conductive component (14) and/or at least a first dielectric component (12); and

one or more pulleys (20,30,40,50) to which the belt (10) is mounted, at least a first of the one or more pulleys (20,30,40,50) having at least one conductive component (22) that, in combination with the first conductive component (14) or the first dielectric component (12) of the belt (10), defines an electrical element chosen from the group consisting of capacitive and resistive elements, at least a portion of the electrical element being located within the belt (10) so as to be physically responsive to transitory and permanent distortions of the belt (10) resulting from extrinsic and/or intrinsic sources; and

means (22) for applying an electrical potential through the electrical element so as to generate an electrical signal from the electrical element corresponding to a physical response of the belt (10) to a transitory and/or permanent distortion.

2. The belt and pulley system (100,200,300,400) of claim 1, wherein the belt (10) consists of the first conductive component (14).

3. The belt and pulley system (100,200,300,400) of claim 1, wherein the belt (10) consists of the first dielectric component (12).

4. The belt and pulley system (100,200,300,400) of claim 1, wherein the belt (10) comprises both the first conductive component (14) and the first dielectric component (12).

5. The belt and pulley system (100,200,300,400) of any of claims 1 to 4, wherein the first pulley (20) comprises the at least one conductive component (22) on a first interior wall (24) of the first pulley (20) and a second conductive component (22) on a second interior wall (24) of the first pulley (20) oppositely disposed from the first interior wall (24), and the portion of the electric element located within the belt (10) is located laterally across the belt (10), through a depth of the belt (10), or a combination thereof between the first and second interior walls (24).

6. The belt and pulley system (100,200,300,400) of any of claims 1 to 4, further comprising a second of the one or more pulleys (20,30,40,50) having at least one conductive component (22) thereon, wherein the portion of the electric element located within the belt (10) is located through the belt (10) between the conductive components (22) of the first and second pulleys (20,30,40,50).

7. The belt and pulley system (100,200,300,400) of claim 6, wherein the portion of the electric element located within the belt (10) is located laterally through a width of the belt (10), through a depth of the belt (10), or a combination thereof between two oppositely-disposed lateral sides of the belt (10) and along the length of the belt (10) between the first and second pulleys (20,30).

8. The belt and pulley system (100,200,300,400) of claim 6, wherein the portion of the electric element located within the belt (10) is located diagonally through the belt (10) from a nonlateral side of the belt (10) to a lateral side of the belt (10) and along the length of the belt (10) between the first and second pulleys (30,40).

9. The belt and pulley system (100,200,300,400) of claim 6, wherein the

portion of the electric element located within the belt (10) is located through a thickness of the belt (10) between two oppositely-disposed nonlateral sides of the belt (10) and along the length of the belt (10) between the first and second pulleys (40,50).

10. A method of sensing the life of a belt (10) using the belt and pulley system (100,200,300,400) according to any of claims 1 to 9, the method comprising:
applying an electrical potential with at least the first pulley (20,30,40,50) and through the electrical element so as to generate an electrical signal from the electrical element corresponding to a physical response of the belt (10) to a transitory and/or permanent distortion;
monitoring the electrical signal; and
removing the belt (10) from the belt and pulley system (100,200,300,400) before catastrophic failure of the belt (10) based on the electrical signal.

11. A method comprising:
providing a belt (10) having at least a first conductive component (14) and/or at least a first dielectric component (12); and
applying an electrical potential through the belt (10) to perform a quality check on the belt (10) to detect damage or a defect in the belt (10) prior to use thereof.

12. A method comprising:
providing a belt (10) having at least a first conductive component (14) and/or at least a first dielectric component (12);
installing the belt (10) on a system (100,200,300,400) comprising at least a first pulley (20,30,40,50) having at least one conductive component (22) that, in combination with the first conductive component (14) or the first dielectric

component (12) of the belt (10), defines an electrical element chosen from the group consisting of capacitive and resistive elements, at least a portion of the electrical element being located within the belt (10) so as to be physically responsive to transitory and permanent distortions of the belt (10) resulting from extrinsic and/or intrinsic sources; and

applying an electrical potential with at least the first pulley (20,30,40,50) and through the electrical element so as to generate an electrical signal from the electrical element corresponding to a physical response of the belt (10) to a transitory and/or permanent distortion.

13. The method of claim 12, wherein the belt (10) comprises both the first conductive component (14) and the first dielectric component (12).

14. The method of any of claims 12 or 13, wherein the electrical potential is applied laterally across a width of the belt (10), through a depth of the belt (10), or a combination thereof between oppositely-disposed first and second portions of the first pulley (20).

15. The method of any of claims 12 or 13, wherein the first pulley (20) comprises the at least one conductive component (22) on a first interior wall (24) of the first pulley (20) and a second conductive component (22) on a second interior wall (24) of the first pulley (20) oppositely disposed from the first interior wall (24), and the electrical potential is applied laterally across a width of the belt (10), through a depth of the belt (10), or a combination thereof between the first and second interior walls (24).

16. The method of any of claims 12 or 13, wherein the electrical potential is applied through the belt (10) between the conductive component (22) of the first

pulley (20,30,40,50) and at least one conductive component (22) of a second pulley (20,30,40,50).

17. The method of claim 16, wherein the electrical potential is applied laterally through the cross-section of the belt (10), through a depth of the belt (10), or a combination thereof, and along the length of the belt (10) between the first and second pulleys (20,30).

18. The method of claim 16, wherein the electrical potential is applied diagonally through the belt (10) and along the length of the belt (10) between the first and second pulleys (30,40).

19. The method of claim 16, wherein the electrical potential is applied through a thickness of the belt (10) and along the length of the belt (10) between the first and second pulleys (40,50).

20. The method of any of claims 12 to 19, further comprising:
detecting an impending failure of the belt (10) based on the electrical signal; and
providing a warning prior to the failure of the belt (10).

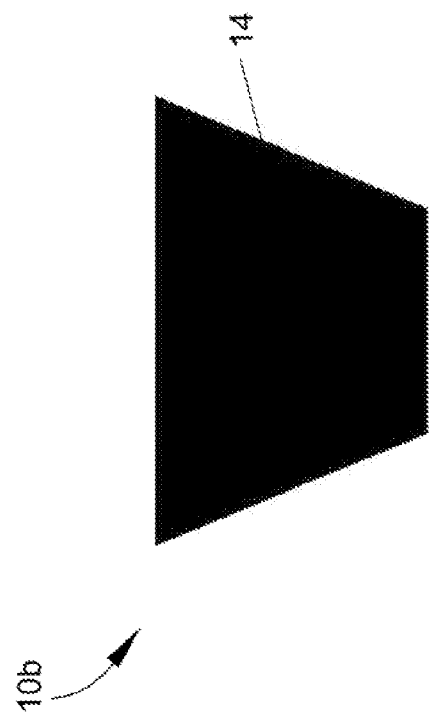


FIG. 1



FIG. 2

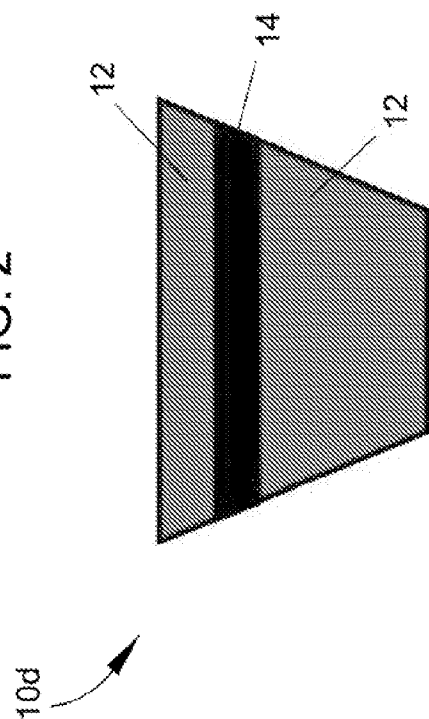


FIG. 3



FIG. 4

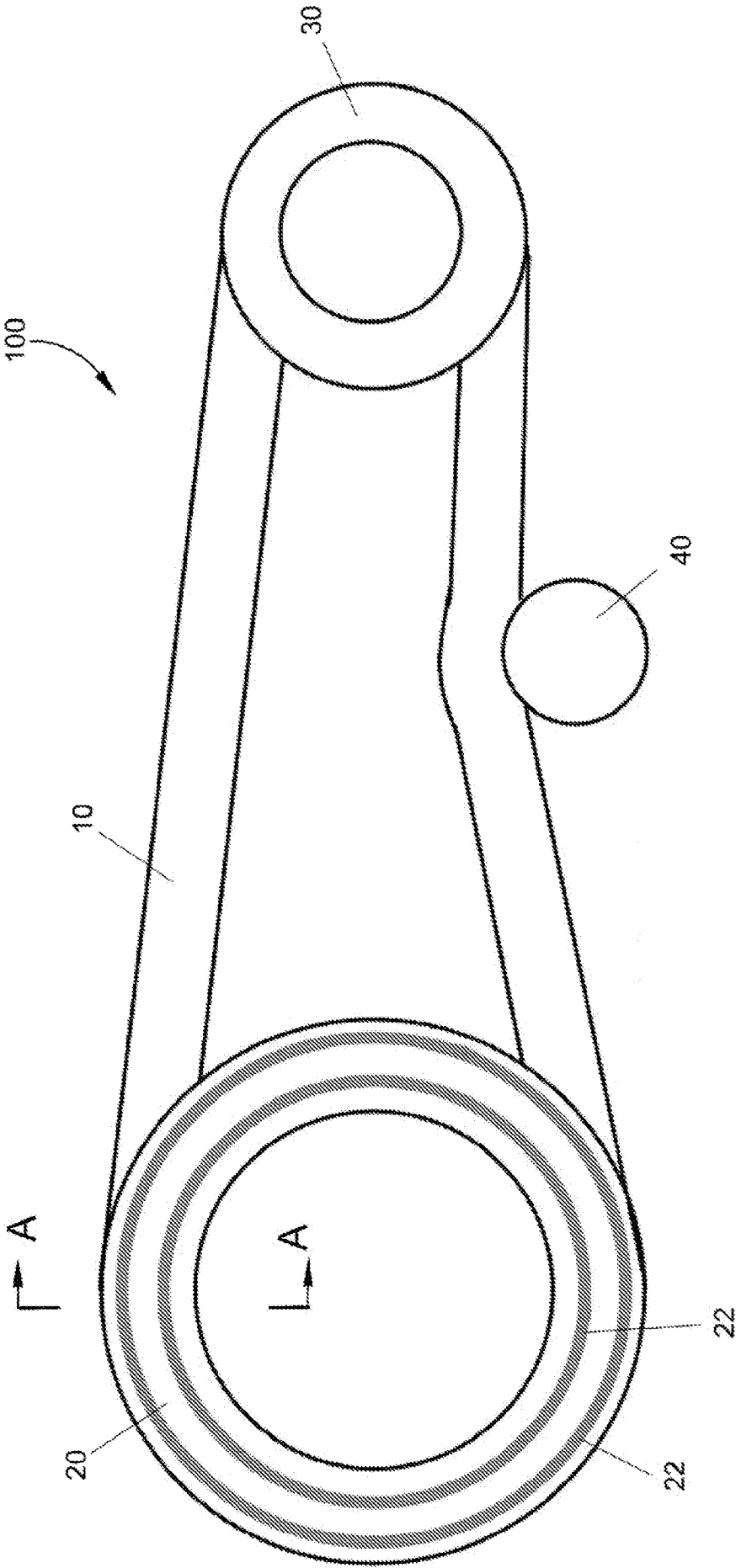
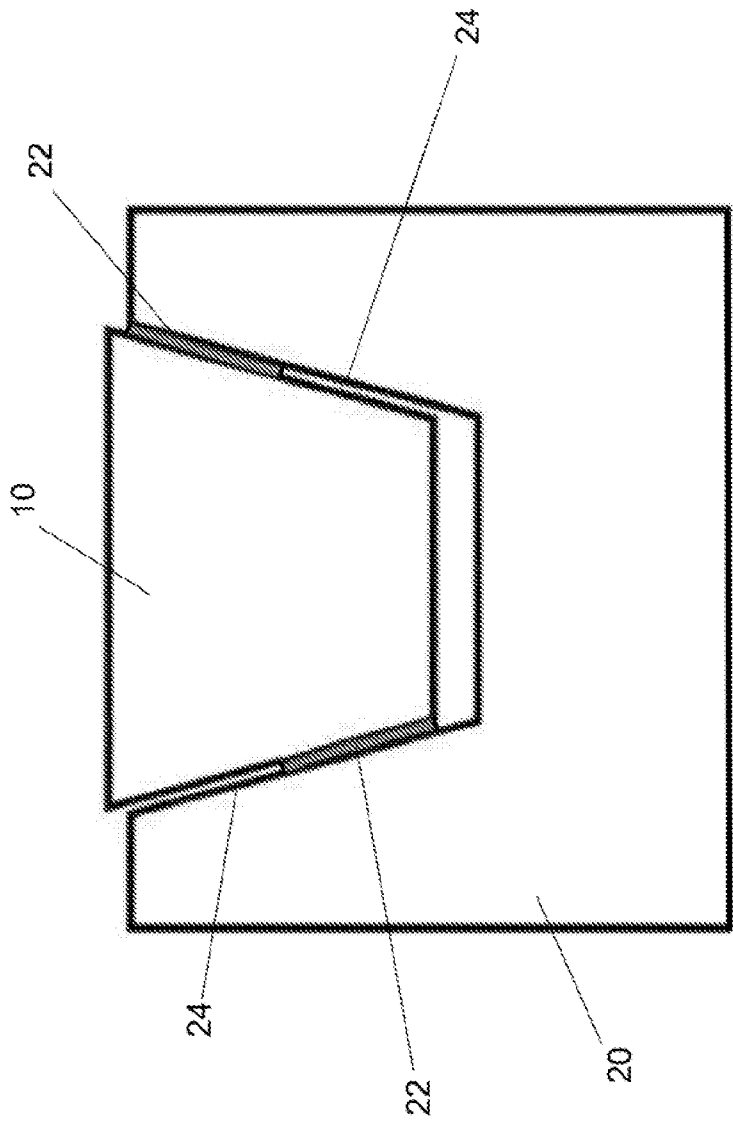


FIG. 5



A-A

FIG. 6

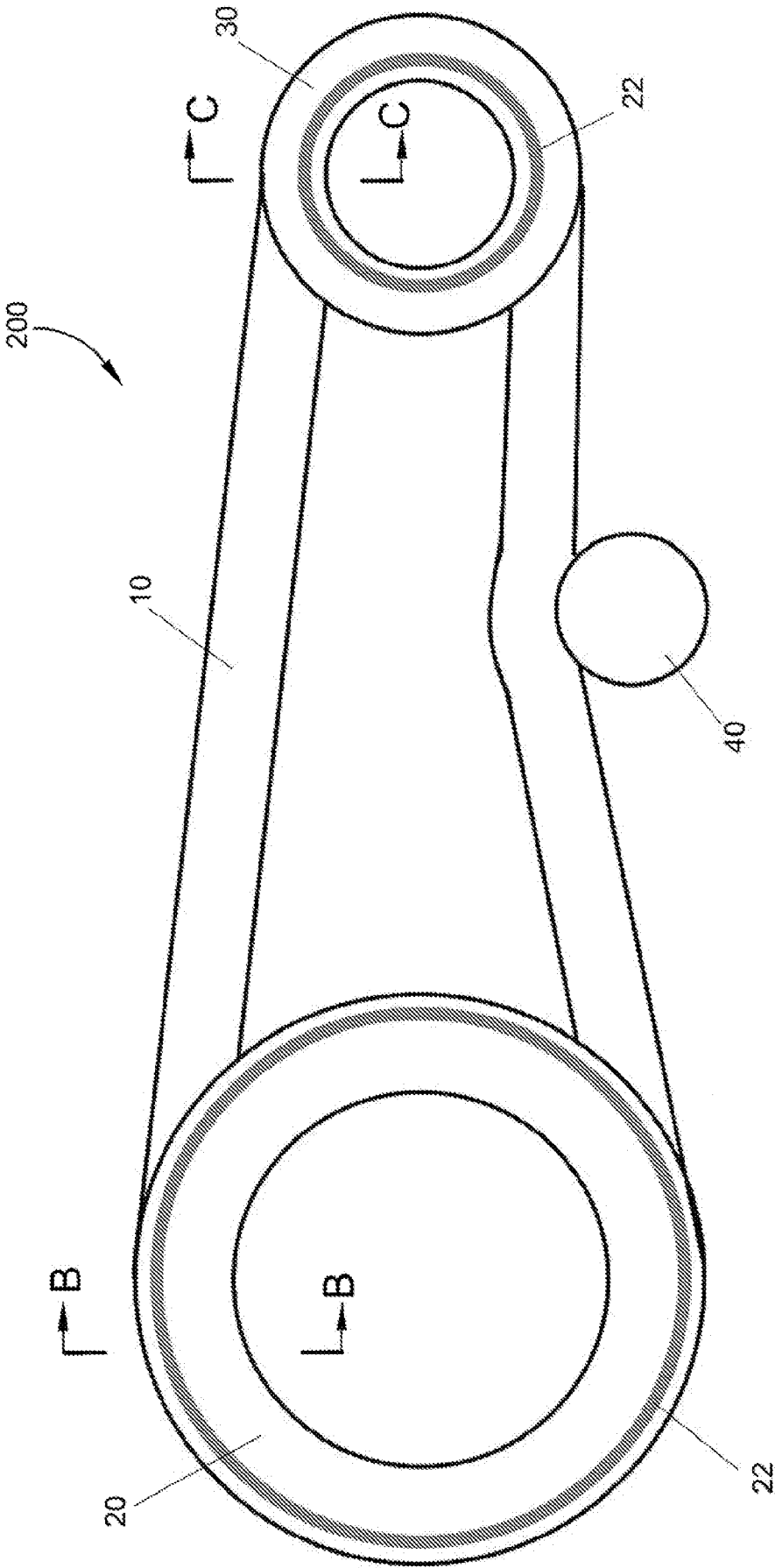


FIG. 7

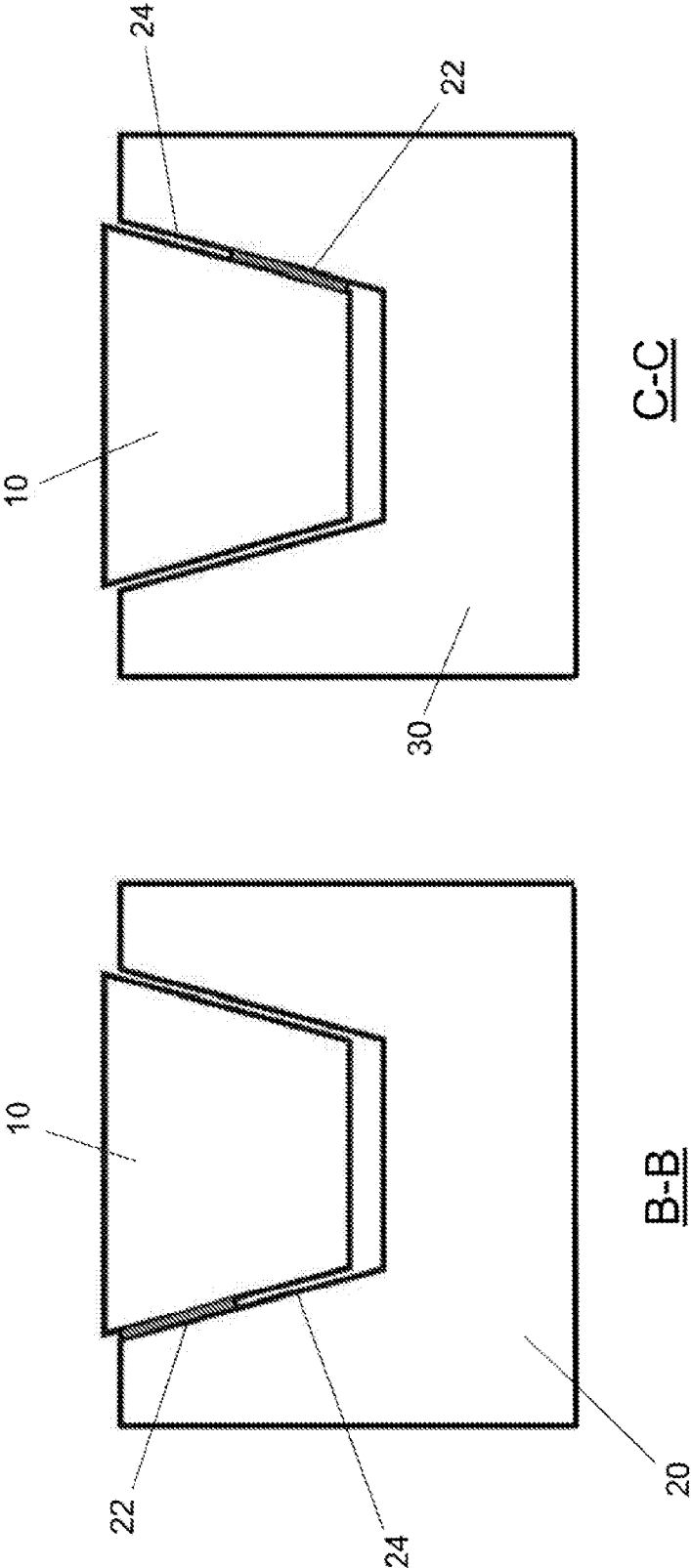


FIG. 8

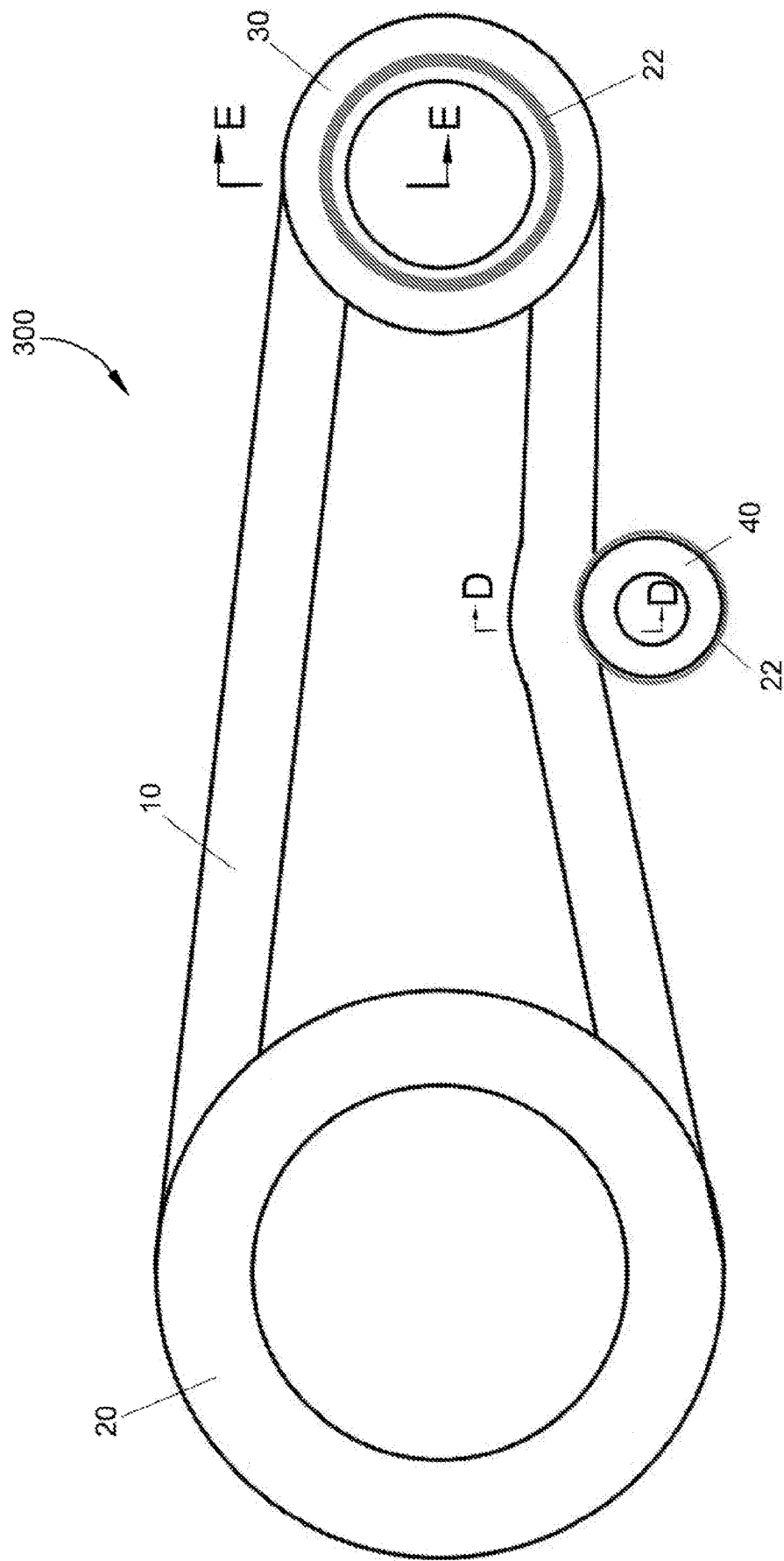


FIG. 9

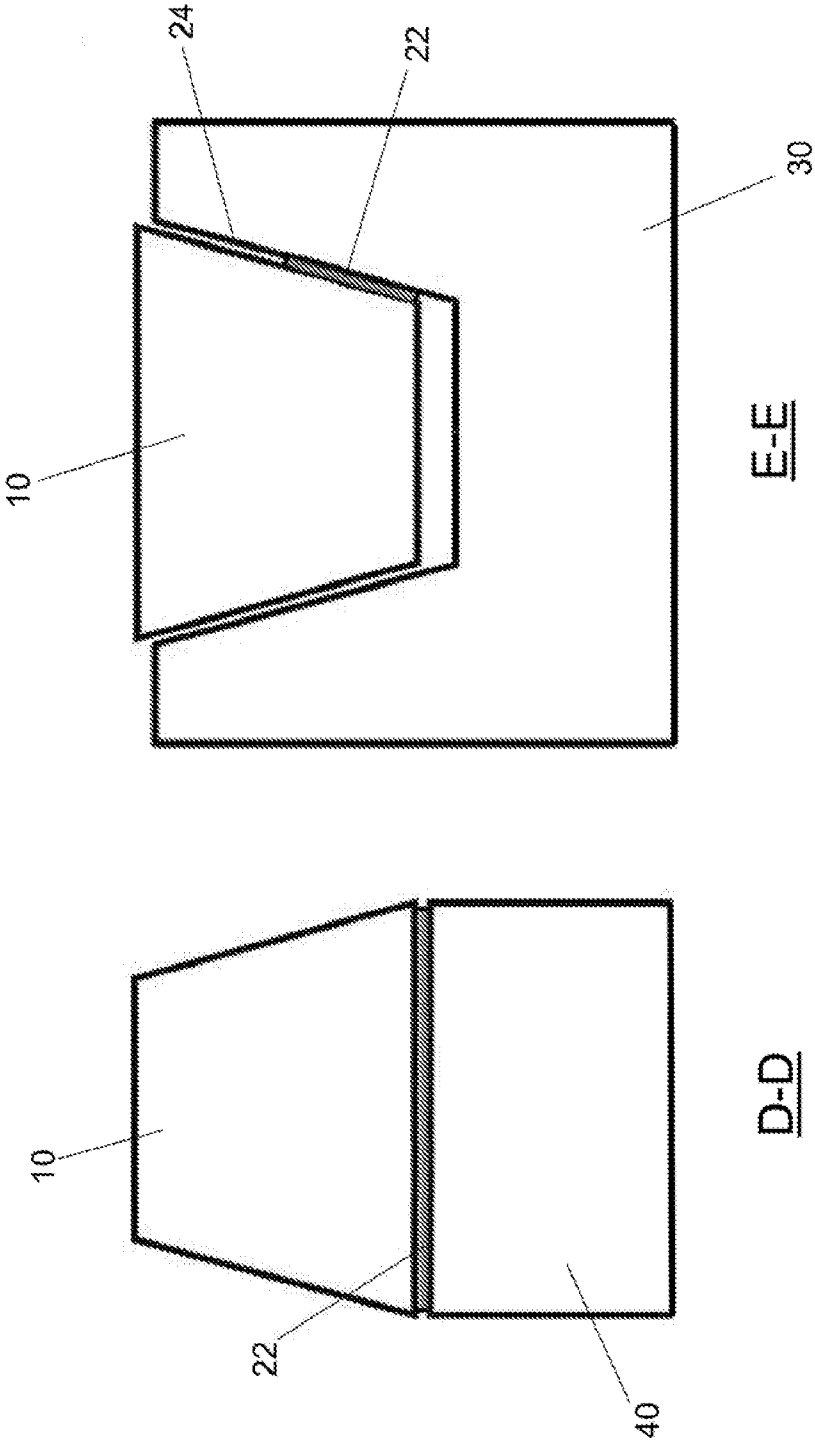


FIG. 10

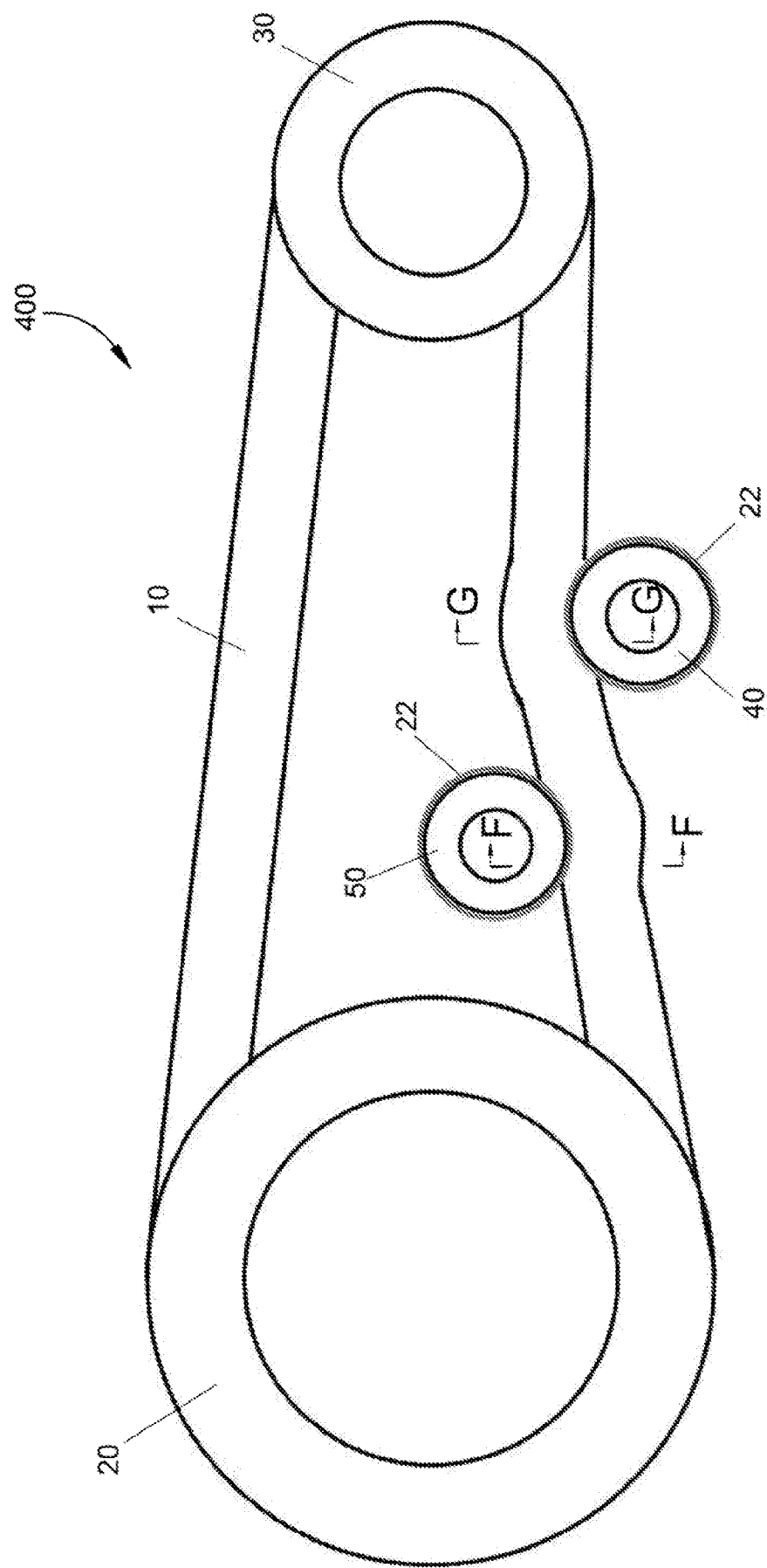


FIG. 11

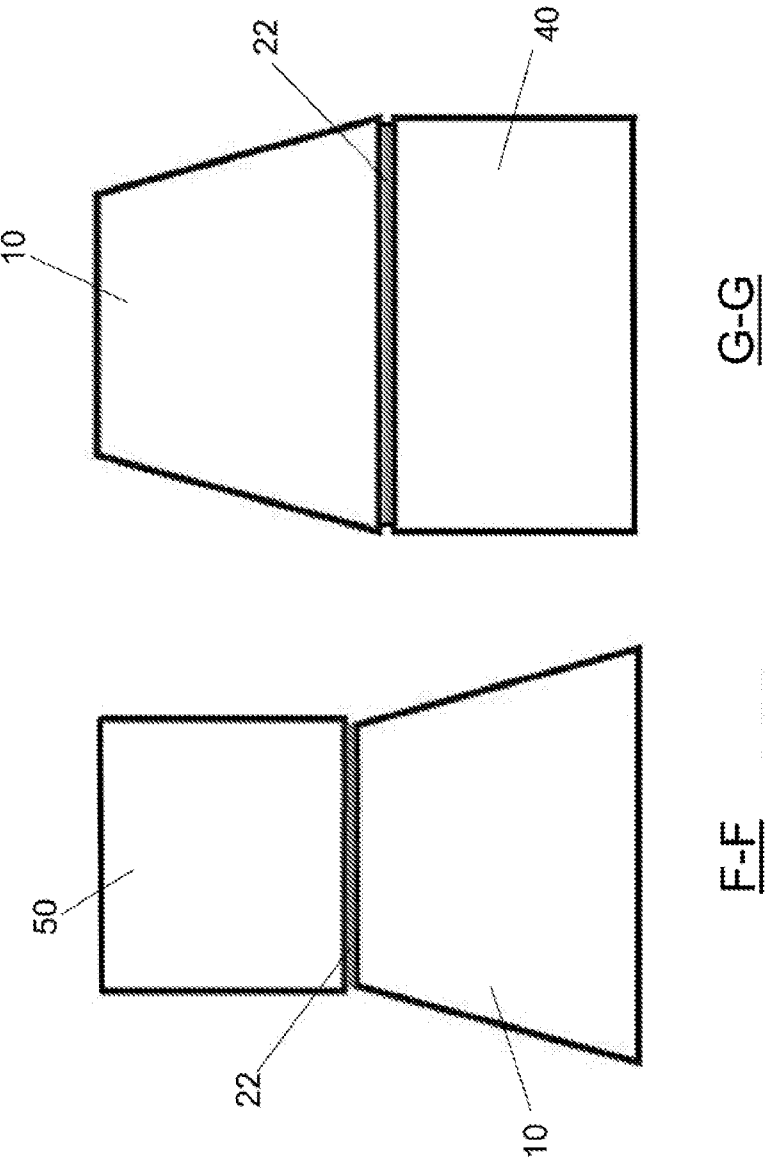


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/019598**A. CLASSIFICATION OF SUBJECT MATTER****F16H 9/12(2006.01)i, F16H 7/08(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16H 9/12; G01M 15/00; F16H 7/00; F16G 1/00; G01N 27/20; F16H 3/08; B60K 17/06; F16H 7/08

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: belt, pulley, damage, conductive, dielectric, resistance, and capacitance

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2005-201408 A (GATES UNITTA ASIA CO.) 28 July 2005 See paragraphs [0014]-[0017], [0020], [0021], [0023]-[0025] and figures 1, 2.	1-9, 11-19
A	JP 09-060694 A (MITSUBISHI HEAVY IND., LTD.) 04 March 1997 See paragraphs [0013]-[0015] and figures 1, 2.	1-9, 11-19
A	JP 2003-014680 A (STAR SEIKI CO., LTD.) 15 January 2003 See paragraphs [0012]-[0016] and figures 1-3.	1-9, 11-19
A	KR 10-0169630 B1 (DAEWOO MOTOR CO., LTD.) 15 January 1999 See claim 1 and figures 1, 2.	1-9, 11-19
A	US 6532810 B1 (AHMED, ADEL ABDEL AZIZ) 18 March 2003 See column 8, line 55 - column 10, line 55 and figures 1A-2.	1-9, 11-19



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

17 May 2016 (17.05.2016)

Date of mailing of the international search report

18 May 2016 (18.05.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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INTERNATIONAL SEARCH REPORTInternational application No.
PCT/US2016/019598**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 10,20
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of any additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/019598

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2005-201408 A	28/07/2005	JP 04178115 B2	12/11/2008
JP 09-060694 A	04/03/1997	None	
JP 2003-014680 A	15/01/2003	None	
KR 10-0169630 B1	15/01/1999	KR 10-1997-0016234 A	28/04/1997
US 6532810 B1	18/03/2003	US 6523400 B1	25/02/2003