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Kitch

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[54] **TORQUE CONTROL METHOD AND APPARATUS**

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[58] **Field of Search**..........................242/75.5, 75.45, 242/75.51, 75.52, 75.53, 67.5

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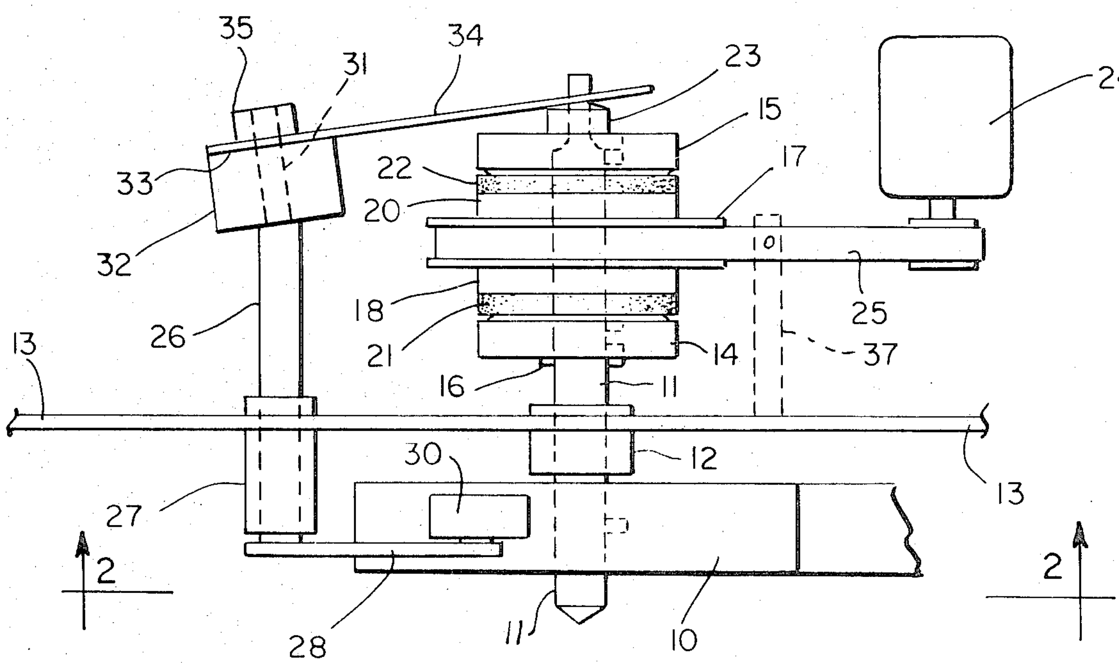
[57] **ABSTRACT**

A method and apparatus for controlling the amount of torque applied to a mandrel in response to a variable condition in which a variable force is obtained by flexing a flexible resilient member in an amount proportional to the variable condition which is sensed, the variable force being utilized to control the amount of torque applied to the mandrel.

In a particular embodiment, the method and apparatus disclosed are employed in winding or unwinding a roll of material in which a variable force is obtained by flexing a flexible resilient member in an amount relating to the diameter of the roll of material being wound or unwound. The roll of material is sensed or monitored to detect changes in its diameter and the variable force generated in accordance with such detected changes is utilized to operate a force-actuated friction clutch for varying the amount of drive torque or braking torque transmitted either from a drive motor or from a brake to the roll of material being wound or unwound in response to the progress of the winding or unwinding, respectively.

11 Claims, 2 Drawing Figures



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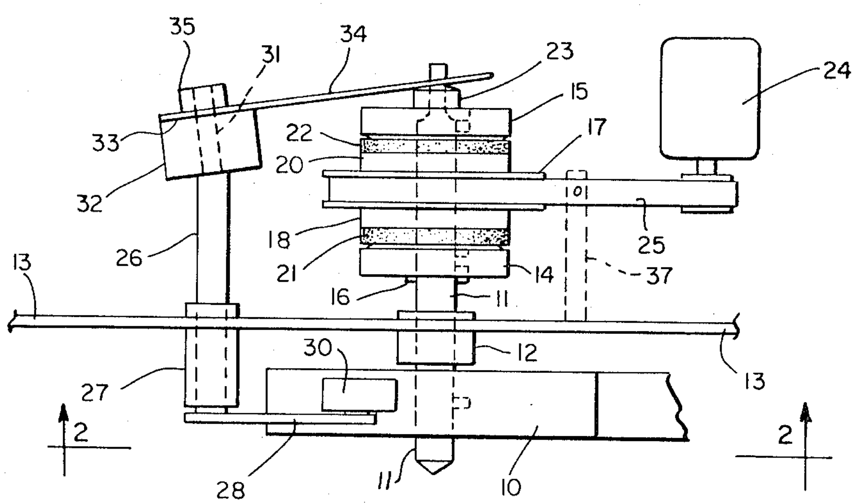

Fig. 1

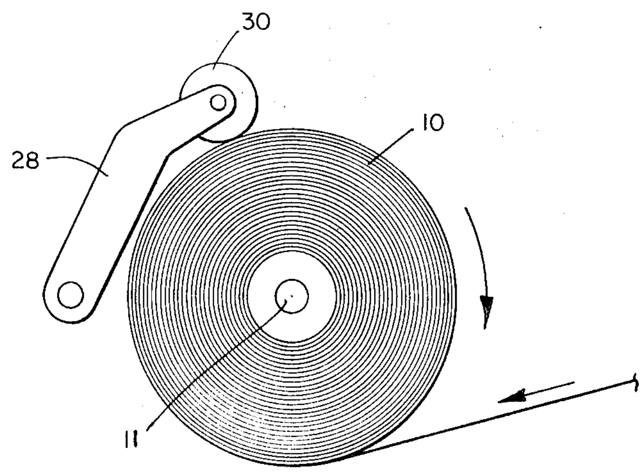

Fig. 2

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TORQUE CONTROL METHOD AND APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and an apparatus for creating a variable force and, more particularly, to a method and an apparatus for controlling the amount of torque applied to a mandrel in response to a variable condition which is monitored or sensed, and specifically to such a method and apparatus used for winding or unwinding a roll of material in which a variable force having a relationship to the progress of the winding or unwinding is created and used to vary the drive or braking torque imparted to the roll of material being wound or unwound, respectively.

2. Brief Description of the Prior Art

In many practical situations, it is often important to control the amount of torque applied to a mandrel in response to a variable condition which can be sensed. In the past, for example, a wide variety of systems have been employed to control either the amount of drive torque transmitted from a drive motor, or the amount of braking torque transmitted from a braking means, to a roll of material being wound or unwound. In particular, such systems have been often employed in winding situations in order to attempt to govern the tension applied to the material being wound or unwound during the course of the winding or unwinding operation, respectively. Thus, it is quite important in practically every winding operation to influence the tension of the material during the progress of the wind so that the material in the interior of the wound roll will not be wrinkled and folded due to increasing web tension when the outer layers of material are applied to the roll. Tension control is a highly critical operation with materials such as low basis weight paper webs where breakout of the web may occur when tension is only slightly exceeded, causing expensive shutdown time and waste of paper in view of the high speed operation of these winders.

In apparatus for film duplication and particularly for microfilm duplication, where a master film and a duplicating film are disposed in face-to-face contact with one another and photographically duplicated by light passing through the master film and striking the duplicating film, variations in the tension of one strip independent of the tension of the other strip during the winding and unwinding of such webs through the system result in serious problems such as double imaging and loss of resolution. Thus, when the original master film moves relative to the duplicate film during the exposure period, due to stretching of one of the films or slippage of one film relative to the other, two or more images are formed and, since such images are not formed by exposure for the full exposure period, each is relatively weak, resulting in further loss of resolution. Accordingly, it is very important in such equipment that a simple and reliable system be provided at many points in the equipment to control the tension of the films being unwound and rewound in conjunction with the duplication process.

Most of the prior art systems for controlling tension in winding and reeling operations, regardless of the particular type, have been fairly large, complex and expensive. In addition, the systems have been difficult to design and fabricate, and in many instances, have not

had the flexibility which would allow easy adjustment to vary the tension.

For example, cam systems have often been employed whereby a programmed cam is utilized to either transmit a variable force to a force-actuated torque clutch mechanism or to apply a braking force to the mandrel on which the material is being wound. Such cams do not have the requisite flexibility and are difficult to design initially due to the large number of factors influencing tension during the wind or unwind. In addition, such cam systems are not readily adjustable for different conditions, since they generally require that a new cam be cut.

In some cases, centrifugal clutch mechanisms have been employed which are speed responsive. However, the rotational speeds of winding drums in film copying apparatus are generally too low to utilize such devices. In addition, such devices do not insure constant tension in the desired manner.

In other instances, electronic systems have been used to control the speed of the drive motor, for example, see U.S. Pat. No. 3,325,114. Other systems have been controlled electronically as by signals which reflect winding speed and control the torque imparted by an electric torque clutch. However, the complexity and expense of these systems in readily apparent. Another common arrangement is to utilize some means to contact the material being wound in order to both measure web tension and generate a force to control the torque imparted to the winding mandrel. Such a device is only operable where substantial variations in web tension are involved.

The present invention provides a new and improved method and apparatus for overcoming many of the disadvantages of the above-mentioned tension control systems. Thus, the apparatus of the invention is quite reliable in construction, low in cost, and can be readily adjusted to generate different tension profiles during the progress of the wind. In addition, the device operates reliably over small changes in the condition being monitored and is not dependent on the speed of travel of the film or web being monitored.

It is the chief objective and advantage of the present invention to create a variable force dependent upon the progress of the winding or unwinding of a roll of material, which force may be used to control the amount of drive torque or braking torque applied to the roll of material by a drive motor or a braking means, respectively.

It is a further objective and advantage of the present invention to control in an improved manner the amount of torque applied to a mandrel in response to a variable condition.

SUMMARY OF THE INVENTION

The invention is a method and apparatus for controlling the amount of torque applied to a mandrel in response to a variable condition. In the invention, force-actuated means are operably connected to the mandrel and vary the amount of torque applied to the mandrel. Sensing means are connected to a rotatably mounted shaft and rotate the shaft when a variable condition being sensed requires a change in the amount of torque applied to the mandrel. A flexible resilient member is operably connected to the force-actuated

means, and flexing means associated with the shaft and operably connected to the resilient member vary the flexure of the resilient member in response to the rotational position of the shaft. In this manner, the resilient member applies a desired force to the force-actuated means, the magnitude of such force being a function of the variable condition.

The invention also includes a method and apparatus for generating a variable force dependent upon the sensed position of an element. The apparatus includes a rotatably mounted shaft and a sensing arm fixed to the shaft for rotation therewith. The sensing arm operably contacts an element, the position of which is to be sensed. A flexible resilient member is flexed by flexing means associated with the shaft and operably connected to the resilient member when it is restrained at a point spaced from the shaft, the flexing means being responsive to the rotational position of the shaft. Thus the member applies a desired force at the point spaced from the shaft, the magnitude of which force is a function of the position of the element.

The invention also includes an embodiment of winding apparatus, which includes force-actuated means to vary the amount of drive torque transmitted from a drive motor to the roll of material being wound in response to the progress of the wind. The method and apparatus described above are utilized in this winding apparatus to create the variable force applied to the force-actuated means and thereby to vary the amount of drive torque utilized in the winding.

The invention further includes an embodiment of unwinding apparatus, which includes force-actuated means to vary the amount of braking torque transmitted from a braking means to the roll of material being unwound in response to the progress of the unwinding. The apparatus described above is also utilized in this unwinding apparatus to create the variable force applied to the force-actuated means and thereby to vary the amount of braking torque utilized in the unwinding operation.

DESCRIPTION OF THE DRAWING

FIG. 1 is a top view of one embodiment of apparatus of the invention, and

FIG. 2 is a sectional side elevation view taken along line 2—2 of FIG. 1.

Referring now to the drawing, a roll **10** of sheet material, such as film or paper, is mounted upon and keyed to an end of a mandrel **11** for rotation therewith. The mandrel **11** is rotatably supported by a bearing **12** mounted in a support plate **13**. The mandrel **11** extends through the support plate **13** and carries on its through-extending end two spaced driven wheels **14** and **15** which are keyed to the mandrel **11** for rotation therewith. Axial movement of driven wheel **14** along mandrel **11** and toward support plate **13** is prevented by a ring **16** affixed to the mandrel **11**. The driven wheel **15** is free to move axially along mandrel **11**. A drive pulley **17** is rotatably mounted on the mandrel **11** between each of the two driven wheels **14** and **15**. The drive pulley **17** is disposed between two coaxial drive wheels **18** and **20** which are affixed to the faces of the drive pulley **17** for rotation therewith. Each of the drive wheels **18** and **20** has a friction plate **21** and **22**, respectively, affixed thereto and directed toward each of the driven wheels **14** and **15**, respectively. The friction plates **21** and **22** frictionally engage the driven wheels **14** and **15**, respectively, upon relative axial movement along mandrel **11** of the respective drive wheel toward the respective driven wheel, and all of these elements from a torque clutch mechanism capable of transmitting a greater amount of torque between pulley **17** and mandrel **11** upon an increase in the axial force between the elements.

A thrust bearing **23** is rotatably mounted on the end of the mandrel **11** adjacent the driven wheel **15** which rotates with the winding mandrel **11**. The bearing **23** provides a nonrotating surface against which an axial force is applied which is to be transmitted to the driven portions of the torque clutch mechanism described above so that the torque transmitted from the drive pulley **17** to the mandrel **11** can be varied. Thus, the bearing **23**, drive pulley **17**, drive wheels **18** and **20**, friction plates **21** and **22** and driven wheels **14** and **15**, respectively, form a force-actuated means for controlling the amount of torque transmitted from drive pulley **17** to the mandrel **11**. Where drive torque is to be transmitted, a drive motor **24** is operably connected to the drive pulley **17** by means of a drive belt **25**.

FIG. **1** of the drawing shows one means for generating a force to be applied to the force-actuated means dependent upon the diameter of the roll **10**. Thus, a shaft **26** is rotatably mounted through the support plate **13** in a position spaced from the mandrel **11** by means of a bearing **27**. One end of the shaft **26** extends through the support plate **13** and carries a sensing arm **28** which is fixed to the shaft **26** for rotation therewith. A follower roller **30** is rotatably carried on the end of the sensing arm **28** remote from the shaft **26** and is arranged to ride in contact upon the outer surface of roll **10** of material on the mandrel **11**.

The instantaneous spatial position or location of the roller **30** during the sensing or monitoring of the diameter of roll **10**, and therefore, the corresponding angular position of the sensing arm **28**, reflects the position of an element or, in the case illustrated in FIG. **1**, the position of the surface of the roll **10** of material on the mandrel **11**. In a winding operation, where winding tension is to be controlled, as FIG. **1** is illustrative of, it reflects the sensed or monitored diameter of the roll **10** of material being wound so that the amount of drive torque transmitted to the winding mandrel can be increased during the progress of the wind as the diameter of the roll increases and the amount of drive torque necessary to maintain a given tension in the material increases.

The shaft **26** rotatably carried by the bearing **27** has an extended portion **31** of lesser diameter disposed at an angle to the rotational axis of the shaft **26**, so that upon rotation of shaft **26**, the extended portion **31** follows a path which delineates a cone. The extended portion **31** of shaft **26** holds a block member **32** which provides a bearing surface **33** inclined at an acute angle to the rotational axis of the shaft **26**. The block member **32** is mounted on the extended portion **31** of the shaft **26** and is fixed thereto for rotation therewith. A flexible resilient member **34** is attached to the extended portion **31** of the shaft **26** by a nut **35** threadedly attached to shaft **26** so as to hold one end of the member **34** in contact with the block member **32**. The opposite end of the member 34 is arranged to contact the thrust bearing 23 and is slotted to allow it to surround the end of the mandrel 11 so that it is held in position and to allow some reciprocal movement to occur when the shaft 26 and extended portion 31 rotate.

The nut 35 can be loosened or tightened in order to adjust the amount of flexure which occurs in the resilient member 34 and accordingly, the force generated thereby for a given sensed condition. This allows the force applied to the torque clutch to be varied between wide limits. Alternatively, the inclination of the bearing surface 33 provided by the block member 32 or the flexure characteristics of the flexible resilient member 34 may be altered to vary the amount of flexure for a given sensed condition. A further alternative for providing adjustment in the amount of flexure for a given value of the sensed condition is to make the extended portion 31 of the shaft 26 rotatable relative to shaft 26 or the arm 28 so that the bearing surface 33 provides a different inclination for the flexible resilient member 34 for a given position of the arm 28. By means of any of the adjustments described above, the force generated by the apparatus for a given condition may be easily and inexpensively varied without the difficulties and shortcomings pointed out above.

In an alternative embodiment of the present invention, where the apparatus of FIG. 1 is utilized to control the braking torque applied to a roll of material, such as when the roll of material is being unwound, a clamp 37 (shown in phantom outline in FIG. 1) secured to support plate 13, may be used to grip the belt 25 so as to firmly hold the drive pulley 17 and drive wheels 18 and 20. When axial movement occurs between the driven wheels 14 and 15 and the drive wheels 18 and 20, respectively, in response to the controlling force generated as described above, braking torque is then applied from the clamp 37 through the drive wheels 18 and 20 to the driven wheels 14 and 15, respectively, to slow the mandrel 11 down, so that tension of the material being unwound from the roll 10 is increased. In all other respects, the apparatus is the same as that shown in FIG. 1 of the drawing. Obviously, different forms of apparatus for providing braking torque to be transmitted might also be utilized.

In the operation of the two embodiments of the apparatus of the invention described above, the roll 10 of film or other sheet material to be wound or unwound is inserted upon the end of the mandrel 11 and keyed thereto for rotation therewith. The follower roller 30 is then placed in contact with the surface of the roll 10 and is biased slightly in contact therewith by the torque imparted to the shaft 26 by the flexure of the flexible resilient member 34. The nut 35 is then adjusted to obtain the desired degree of flexure of the flexible member 34 so that the opposite end of the flexible member 34 presses against the stationary surface of the thrust bearing 23 with a force which transmits the desired amount of torque through the friction clutch for the winding of the roll 10 when the roll 10 has any given diameter.

If the friction clutch is being utilized to transmit drive torque to the mandrel 11, the motor 24 is used to drive the pulley 17 by means of the belt 25, and friction generated by the various elements in the friction clutch, as described previously, causes torque to be transmitted to the winding mandrel 11. As previously indicated, the amount of force applied to the thrust bearing 23 by the flexible resilient member 34 directly controls the amount of torque transmitted to the mandrel 11, since the amount of friction created between the various discs or wheels of the friction clutch is directly proportional to the axial force between the discs or wheels.

Of course, where the apparatus is used to apply a braking torque to the mandrel 11, the clamp 37 prevents rotation of the pulley 17 by means of belt 25. In this mode of operation, the force generated by the end of flexible resilient member 34 against thrust bearing 23 similarly controls the amount of braking torque which is transmitted from the stationary pulley 17 to the mandrel 11 through the friction clutch.

From the above description of the invention, it is apparent that the invention provides a new and improved method and form of apparatus for controlling the amount of torque applied to a mandrel in response to a variable condition, which can be used for varying the force applied to a torque clutch in winding or unwinding apparatus in response to the sensed position of an element or the diameter of a roll of material being wound or unwound. The apparatus can be seen to have particular utility in an apparatus such as film duplication equipment where tension of a large number of winding and unwinding mandrels must be controlled. In that instance, all of the mandrels may be driven by a single drive belt operating off of one drive motor and the requisite torque clutches and force generating means may be quite small and conveniently located where necessary. It is also apparent that the inherent simplicity of the apparatus insures that the apparatus is highly reliable in operation and will operate at very low speeds as well as at higher speeds. In addition, it can be seen that adjustment of the apparatus for providing different actuating forces in response to the same sensed or monitored conditions can be readily and conveniently made.

From the above description, it will be apparent that numerous changes might be made in the details of the apparatus described without departing from the spirit and scope of the invention. For example, the flexible resilient member might comprise a flexible resilient disc or other shape of plate rather than an elongate member and would function in a similar manner. In addition, different forms of torque clutches might be utilized, all of which operate to vary the torque transmitted from a drive motor to a shaft by means of a variable force. Moreover, the flexing means associated with the shaft may be of many different types and the particular form thereof is not critical. Therefore, the invention is not intended to be limited except as may be required by the following claims.

What is claimed is:

1. Apparatus for generating a variable force dependent upon the sensed position of an element, comprising

a rotatably mounted shaft,

a sensing arm fixed to said shaft for rotation therewith, said sensing arm operably contacting an element, the position of which is to be sensed, whereby said sensing arm causes said shaft to rotate in response to a change in the position of said element, a flexible resilient member,

flexing means associated with said shaft operably connected to said resilient member so as to vary the flexure of said resilient member when it is restrained at a point spaced from said shaft, said flexing means being responsive to the rotational position of said shaft, said flexing means including means on said shaft defining a bearing surface inclined at an acute angle to the rotational axis of said shaft and capable of changing its direction of inclination in response to rotation of said shaft, and means for retaining said resilient member in contact with said bearing surface to flex said resilient member as said shaft is rotated and apply a desired force at said point, the magnitude of which force is a function of the position of said element.

2. Apparatus according to claim 1, wherein said flexing means further includes

an extended portion of said shaft disposed at an angle to the rotational axis of said shaft so that, upon rotation of said shaft, the extended portion follows a path which delineates a cone, said extended portion being connected to said bearing surface for causing change in direction of inclination of said bearing surface when said shaft rotates.

3. Apparatus according to claim 1, wherein

said flexible resilient member comprises a plate mounted upon said bearing surface and having portions extending outwardly about the periphery of said bearing surface.

4. In winding apparatus, including force-actuated means to vary the amount of drive torque transmitted from a drive motor to the roll of material being wound in response to the progress of the wind, the improvement comprising

a rotatably mounted shaft,

a sensing arm fixed to said shaft for rotation therewith, said sensing arm operably contacting the surface of the roll of material being wound, whereby said sensing arm causes said shaft to rotate in response to changes in the diameter of the roll of material being wound,

a flexible resilient member operably connected to said force-actuated means, and

flexing means associated with said shaft and operably connected to said resilient member so as to vary the flexure of said resilient member, said flexing means being responsive to the rotational position of said shaft, said flexing means including means on said shaft defining a bearing surface inclined at an acute angle to the rotational axis of said shaft and capable of changing its direction of inclination in response to rotation of said shaft, and means for retaining said resilient member in contact with said bearing surface, whereby said resilient member is flexed as said shaft is rotated,

whereby said resilient member applies a desired force to said force-actuated means, the magnitude of said force being a function of the diameter of the roll of material being wound.

5. The improvement in winding apparatus according to claim 4, wherein said flexing means further includes

an extended portion of said shaft disposed at an angle to the rotational axis of said shaft so that, upon rotation of said shaft, the extended portion follows a path which delineates a cone, said extended portion being connected to said bearing surface for causing change in direction of inclination of said bearing surface when said shaft rotates.

6. The improvement in winding apparatus according to claim 4, wherein

said flexible resilient member comprises a plate mounted upon said bearing surface and having portions extending out-wardly about the periphery of said bearing surface.

7. Winding apparatus comprising

a rotatably mounted mandrel supporting a roll of material being wound,

force-actuated means for applying varying amounts of drive torque to said mandrel during the progress of the wind, said means including

a drive wheel mounted for rotation on said mandrel,

drive means operably connected to said drive wheel, and

at least one driven wheel secured to said mandrel for rotation therewith, said drive wheel and said driven wheel being axially movable relatively and being engageable with one another to a varying degree depending upon the axial force applied thereto, and

drive torque control means for varying the force applied to said force-actuated means to vary the drive torque transmitted to said mandrel in response to changes in the diameter of the roll of material being wound, said drive torque control means including

a rotatably mounted shaft,

a sensing arm fixed to said shaft for rotation therewith, said sensing arm operably contacting the surface of the roll of material being wound, whereby said sensing arm causes said shaft to rotate in response to changes in the diameter of the roll of material being wound,

a flexible resilient member operably connected to said force-actuated means, and

flexing means associated with said shaft and operably connected to said resilient member so as to vary the flexure of said resilient member, said flexing means being responsive to the rotational position of said shaft,

whereby said resilient member applies a desired force to said force-actuated means, the magnitude of said force being a function of the diameter of the roll of material being wound.

8. Apparatus according to claim 7, wherein said flexing means comprises

means on said shaft defining a bearing surface inclined at an acute angle to the rotational axis of said shaft and capable of changing its direction of inclination in response to rotation of said shaft, and means for retaining said resilient member in contact with said bearing surface, whereby said resilient member is flexed as it is rotated.

9. Apparatus according to claim 7, wherein said flexible resilient member comprises a plate mounted upon said bearing surface and having portions extending outwardly about the periphery of said bearing surface.

10. In unwinding apparatus, including force-actuated means to vary the amount of braking torque trans-

mitted to the roll of material being unwound in response to the progress of unwinding, the improvement comprising

a rotatably mounted shaft,

a sensing arm fixed to said shaft for rotation therewith, said sensing arm operably contacting the surface of the roll of material being unwound, whereby said sensing arm causes said shaft to rotate in response to changes in the diameter of the roll of material being unwound,

a flexible resilient member operably connected to said force-actuated means, and

flexing means associated with said shaft operably connected to said resilient member so as to vary the flexure of said resilient member, said flexing means being responsive to the rotational position of said shaft, said flexing means including means on said shaft defining a bearing surface inclined at an acute angle to the rotational axis of said shaft and capable of changing direction of inclination in response to rotation of said shaft, and means for retaining said resilient member in contact with said bearing surface, whereby said resilient member is flexed as said shaft is rotated,

whereby said resilient member applies a desired force to said force-actuated means, the magnitude of said force being a function of the diameter of the roll of material being unwound.

11. A method for generating a force for controlling the amount of torque transmitted to a roll of material being wound or unwound, in response to the progress of the winding or unwinding, including the steps of:

sensing the diameter of the roll of material being wound or unwound,

rotating an element through an angle proportional to the sensed diameter of the roll being wound, said element comprising a rotatably mounted shaft and means on said shaft defining a bearing surface inclined at an acute angle to the rotational axis of said shaft and capable of changing its direction of inclination in response to rotation of said shaft, and a flexible resilient member having one part in contact with said bearing surface and another part in operable contact with a remote point, and

flexing said resilient member in an amount proportional to the diameter of the roll being wound or unwound by changing the direction of inclination of said bearing surface, whereby said resilient member applies a force at said remote point in an amount proportional to the diameter of the roll being wound or unwound, which force is utilized to control the amount of torque applied to said roll of material being wound or unwound.

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