United States Patent

Martin

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[45] **May 2, 1972**

[54] TENSION REGULATION APPARATUS

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[52] **U.S. Cl.** **226/195,** 226/25, 226/44, 74/572

[51] **Int. Cl.** **B65h 23/18**

[58] **Field of Search** 226/195, 25; 74/572

[56] **References Cited**

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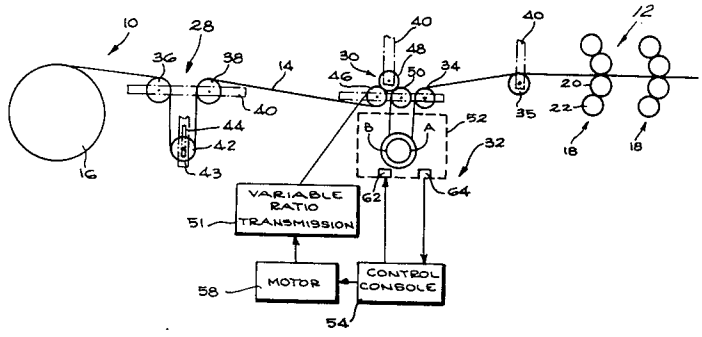
Primary Examiner—Allen W. Knowles

Attorney—Fitch, Even, Tabin & Luedeka

[57] **ABSTRACT**

Apparatus for preventing a change in the tension in one region of a moving web from causing a change in the tension in another region of the web. An assembly which is movable translationally and rotationally by a force applied by a change in web tension at one of two engagement lines between the assembly and the web, has masses which are so distributed that a change in force applied at one of the lines produces substantially no acceleration of the assembly at the other engagement line.

9 Claims, 9 Drawing Figures



Patented May 2, 1972 3,659,767

2 Sheets-Sheet 1

FIG.1

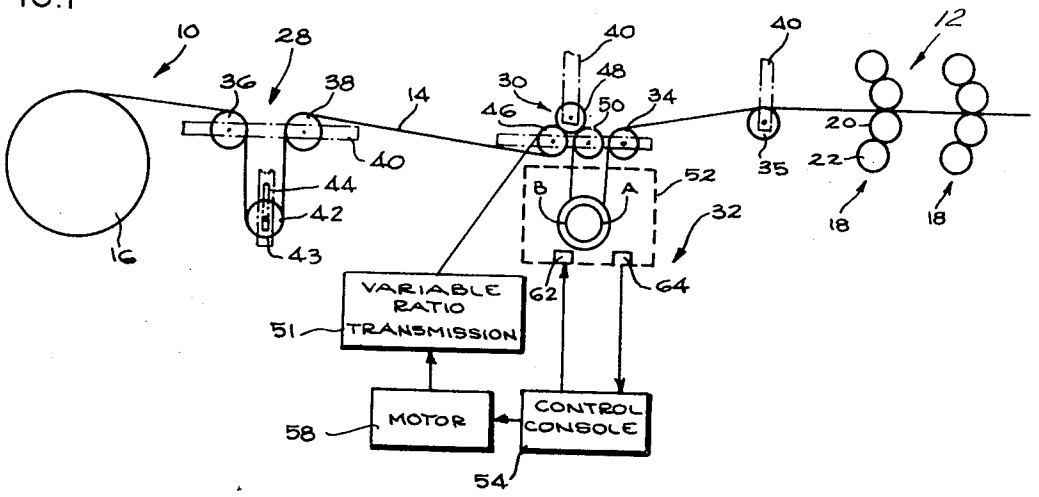


FIG.2

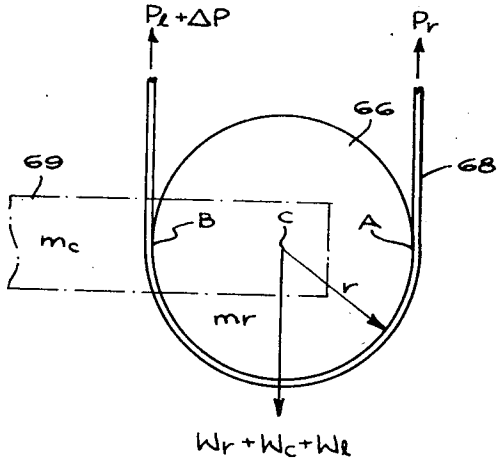
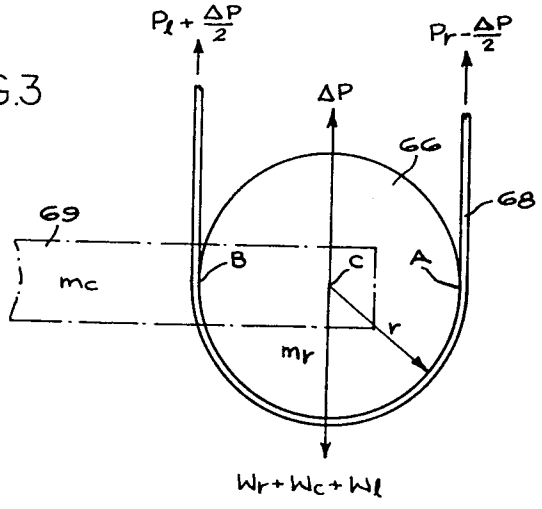


FIG.3



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Patented May 2, 1972 3,659,767

2 Sheets-Sheet 2

FIG. 4

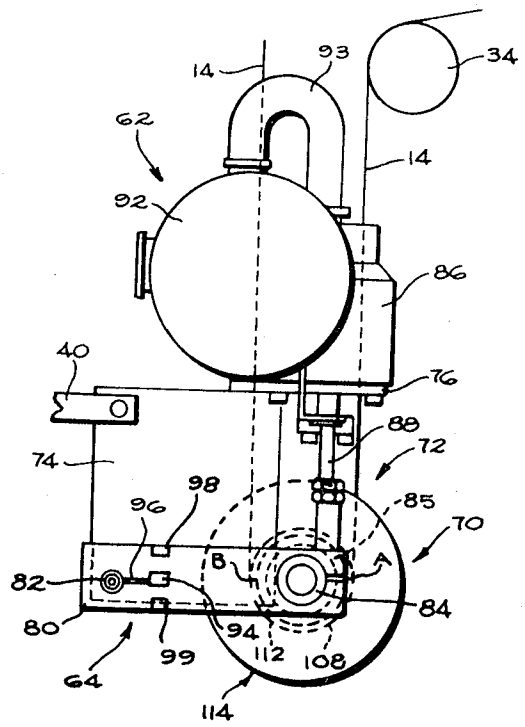


FIG. 5

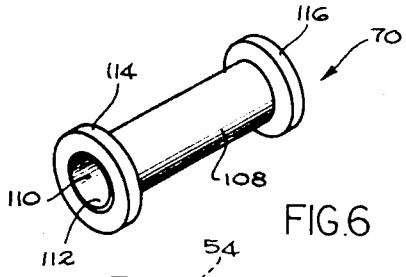


FIG. 6

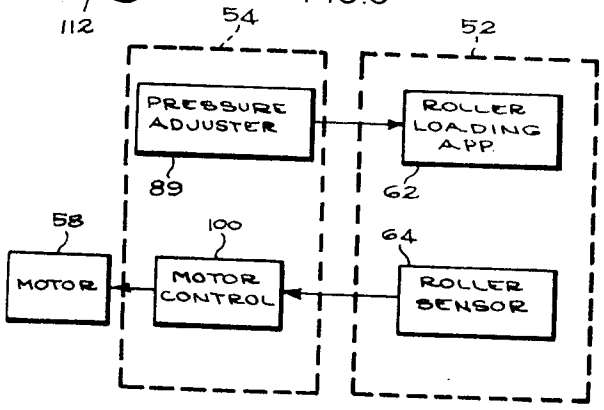


FIG. 7

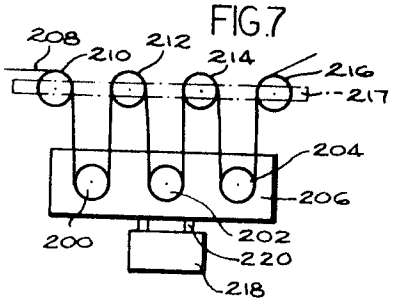


FIG. 8

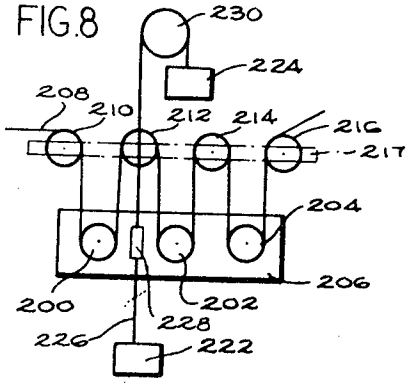
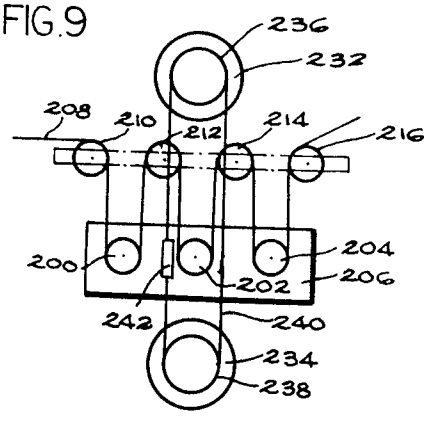


FIG. 9



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TENSION REGULATION APPARATUS

This invention relates to the regulation of tension in a flexible member and, more particularly, to apparatus for preventing fluctuations in tension in one region of a moving web from causing tension changes in another region of the web. As used herein the term "web" is intended to include all forms of flexible members such as wires, filaments, textile yarn, etc.

A recurring problem in systems for performing operations on webs of paper, cloth or other suitable material is the regulation of web tension. Such problems may arise in a number of arts such as printing, film and plastic processing, and magnetic tape recording. In the operation of high speed continuous printing presses the problems of regulating web tension are particularly important. Failure to prevent tension changes in a moving paper web results in stretching and shrinking of the web along its length. When this occurs in the region in which the web is being printed it leads to defects in the printed product such as slurring, doubling and ghosting of images, color misregister, and if the tension becomes too great, breaking of the web and interruption of operations.

Unfortunately there are several causes of tension fluctuation in printing press operation which seem to be unavoidable. These include variations in the web's modulus of elasticity due to material irregularities or changes in temperature or humidity, rolls which have flat spots or are elliptical in cross section, drifting in the speed of the various drive rolls and the supply roll, irregularities in the operation of braking mechanisms, and the operation of flying pasters which join one supply roll to another while the press is in operation.

A number of means have been developed to regulate or control tension, none of which completely solve the problem of preventing transient changes or fluctuations in tension in one region of the web from causing tension changes in other regions. One approach has been to utilize one or more dancer rolls — floating rotating cylinders each of which, when placed between two idler rolls and offset therefrom, constrains the web into a loop and exerts force on the bight of the loop. This force, which may be a result of the weight of the dancer or of a force exerted on the dancer by a spring, a fluid pressure actuated cylinder, or an external weight, or some combination thereof, establishes an average level of tension in the loop. It does not, however, completely compensate for changes in web tension on one side of the dancer which usually cause tension changes on the other side of the dancer.

Consequently, devices have been developed in which the position of a roller, which changes as the web tension changes, is sensed to produce an input signal for a control circuit. The control circuit may be used to adjust another parameter which can affect web tension such as the speed of the supply roll or of drive rolls thus readjusting the web tension to compensate for the initial change and restoring the dancer to its initial position. These devices have also been deficient since their response cannot be instantaneous and some tension fluctuations still propagate past the tension measuring roll.

Accordingly, a need exists for web tension regulation apparatus which prevents fluctuations in one region of a web from causing tension changes in another region of the web.

It is, therefore, an important object of the invention to provide improved web tension regulation apparatus which prevents the propagation of tension fluctuations from one region of the web to another.

Another object of the invention is to provide tension regulation means which is effective, yet simple in construction and operation and inexpensive to build.

Yet another object of the invention is to provide tension regulation means which can be easily installed in an existing web handling apparatus.

Still another object of the invention is to provide a tension regulation system which completely absorbs tension fluctuations rather than merely partially compensating therefor.

A more specific object of the invention is to provide an improved floating roller assembly for regulating web tension.

Other objects and advantages of the invention will become apparent from the following description and the accompanying drawings in which:

FIG. 1 is a schematic illustration of a portion of a web handling system showing various features of the invention;

FIG. 2 is a force and torque diagram of a floating roller considered as a free body when a tension change occurs in one leg of the web;

FIG. 3 is a force and torque diagram equivalent to FIG. 2 in which the dynamic analysis is made more easily;

FIG. 4 is a partially schematic elevational view of a tension regulation apparatus according to the invention which may be utilized in the system of FIG. 1;

FIG. 5 is a perspective view of the floating roller of FIG. 4;

FIG. 6 is a schematic diagram of the control means for the apparatus of FIGS. 4 and 5; and

FIGS. 7, 8 and 9 are schematic views of other forms of tension regulation apparatus showing various features of the invention.

Very generally, a web handling system such as is illustrated in FIG. 1 includes a supply section **10** and an operating section **12** in which desired operations are performed on a web **14**. As schematically illustrated in FIG. 1, the supply section **10** comprises an unwinding or supply roll **16** on which the web is carried and the operating section **12** is a rotary offset printing press with a plurality of printing units **18** each including two blanket rolls **20** engaging the web and printing both sides thereof and two plate rolls **22** from which ink is transferred to the blanket. It will be appreciated that these features of a web handling system are merely illustrative and that other operations such as cutting or perforating, etc., could be performed by such a system. Moreover, the tension regulating apparatus of the present invention could be installed at any point along a web path where this function is desirable.

Between the supply section **10** and the operating section **12** various subsidiary operations may be performed on the web, including the important operation of tension regulation. In the illustrated system, the web first passes through a conventional dancer roll assembly **28**, thence through an infeed drive assembly **30**, tension regulation apparatus **32**, and over idler rollers **34** and **35** for adjusting the vertical position of the web path for feeding into the printing section **12**.

The dancer roll assembly **28** comprises two idler rollers **36** and **38** rotatably mounted in a framework **40** and a dancer roller **42** which is supported by the web **14** between the idler roller to form a loop in the web. The dancer roller **42** has trunnions **43** extending into vertical channels **44** on the framework. The dancer roller **42** is thus movable vertically so as to take up any slack in the loop caused by speed changes in the supply roll.

The infeed drive assembly **30** as illustrated is a positive drive comprising three driver rollers **46**, **48** and **50**, rotatably mounted on the framework **40** and defining nips between rollers **46** and **48** and rollers **48** and **50**, respectively. The web is wound in serpentine fashion successively around each of the driver rollers **46**, **48** and **50**. The speed of the driver rollers relative to the rest of the system is adjustable by means of a variable ratio transmission **51**, the automatic adjustment of which is described in detail in connection with the description of the tension regulating apparatus **32**.

The tension regulating apparatus as schematically illustrated in FIG. 1, generally comprises a floating roller assembly **52** which is tangent to the web along lines A and B and in non-slipping contact therewith at least along those lines and thus defines two regions of the web on each side of the assembly adjacent the lines A and B respectively. The apparatus **32** also includes a control console **54** operatively connected to the infeed drive assembly **30** through a motor **58** and variable ratio transmission **51**. The control console is also operatively connected to a roller loading apparatus **62** and a roller sensing apparatus **64** included in the roller assembly **52**.

Before describing the tension regulating apparatus **32** in greater detail, it is desirable to consider the effects of forces

and torques exerted on a single floating roller which separates two regions of a moving web. The analysis may, of course, be extended to multiple roller systems. Referring to FIG. 2, a floating roller **66** has a radius r and mass m_r with its axis at C. It is supported in the bight of a loop of a web **68** and constrained laterally by a constraining structure **69**. The web may for example be moving from left to right, and the roller is free to move vertically and to rotate about its axis. The web and roller are tangent to one another along lines A and B parallel to the roller axis and in non-slipping engagement with one another. Under steady state conditions the roller would have equal forces, Pl and Pr applied by the web, which to maintain equilibrium, will together be equal to the weight of the roller Wr with the effective weight Wc of the structure **69** plus any external roller loading Wl. Pl represents the tension on the left side of the roller while Pr represents the tension on the right side of the roller. For the purposes of analyzing the transient response of the roller, a tension disturbance Δ P will be introduced on the left side of the roller. This represents a tension disturbance which could be introduced by an out-of-round roll, a flying splice, or stick-slip in the unwind hold-back system. It is commonly assumed that because of roller inertias, these disturbances, or at least a portion of them, would be transmitted to the other side of the roller.

The analysis of a floating roller system ordinarily is concluded at this point, without regard to the rotational effects of forces, which effects are related to the moment of inertia of the roller, since these are commonly thought to be insurmountable. However, consideration of such effects reveals the deficiencies of the prior art systems. FIG. 2 can be drawn in a more convenient form shown in FIG. 3. In this form, the accelerations of the roller are easily calculable as follows:

The translational acceleration will be calculated in the form

$$F = Ma \tag{1}$$

F_T is the summation of translational forces acting on the dancer, or

$$F_T = P_l + (\Delta P/2) + \Delta P + P_r - (\Delta P/2) - (W_r + W_c + W_l). \tag{2}$$

Since

$$W_r + W_c + W_l = P_l + P_r, \tag{3}$$

then

$$F_T = \Delta P \text{ (the assumed tension disturbance).} \tag{4}$$

If M is the mass m_r of the roller plus the equivalent mass m_c of the constraining structure, and a is the upward translational acceleration of the roller this acceleration is, then, $\Delta P/M$, and is common to all portions of the roller.

The rotational acceleration will be calculated in the form

$$T = I\alpha, \tag{5}$$

where I is the moment of inertia of the roller about its axis and α is the angular acceleration of the roller. The net torque I *about the center of the roller is given by*

$$T = \left\{P_1 + \frac{\Delta P}{2}\right\} r - \left\{P_r - \frac{\Delta P}{2}\right\} r \tag{6}$$

Since

$$P_r = P_l, \tag{7}$$

then

$$T = r\Delta P. \tag{8}$$

The inertia I is equal to $m_r k^2$, where k is the radius of gyration of the roller and as previously noted, m_r is the mass of the roller. Therefore,

$$\alpha = T/I = (r\Delta P/m_r k^2) \tag{9}$$

Since tangential acceleration equals αr, the tangential acceleration αt_B of Point B is given by

$$\alpha t_B = (r^2 \Delta P/k^2 m_r) \tag{10}$$

and the tangential acceleration αt_A of Point A is given by

$$\alpha t_A = -(r^2 \Delta P/k^2 m_r) \tag{11}$$

Summing the accelerations due to both rotation and translation at Point A and Point B shows that the upward acceleration a_B of Point B is given by

$$a_B = (\Delta P/M) + (\Delta P\, r^2/m_r k^2) \tag{12}$$

and that the net acceleration a_A of Point A is given by

$$a_A = (\Delta P/M) - (\Delta P\, r^2/m_r k^2) \tag{13}$$

if the assembly of the roller and the supporting structure is such that

$$\Delta P/M = (\Delta P\, r^2/m\, k^2), \tag{14}$$

then the acceleration at Point A will equal zero. This means that the tension disturbance, ΔP, on the left hand portion of web, while accelerating Point B, causes no acceleration at Point A, and consequently no tension disturbance in the right hand section of web — the desired result.

Another way of stating this requirement is that conjugate centers of percussion of the assembly of the roller and the constraining structure, must be established at the two lines of tangency of the roller assembly and the web. If this is the case, all of the energy imparted to the roller assembly by a tension disturbance in the web on one side of the roller assembly, will be absorbed by the roller assembly, without disturbing the web on the other side of the roller assembly. Since M must be greater than m_r, and the radius of gyration k of a physically realizable cylinder is less than its radius r, the desired condition cannot be realized with a plain cylindrical roller.

Accordingly an important aspect of the invention is to provide a floating roller assembly between two regions of a web with masses and moments of inertia such that when a tension change occurs in the web in the region adjacent to one line of tangency and non-slipping contact between the web and apparatus, at another line of tangency and non-slipping contact with the web adjacent the other region, there is no change in acceleration parallel to the web along the other line. Thus the original transient tension change is completely absorbed.

Although the desired condition cannot be realized in a single roller system with a plain cylindrical roller, the applicant has discovered that it can be accomplished in other configurations. One method is that of adding mass to the system which shares the rotational motion of the roller, but is positioned outside of radius at which the web contacts the roller. Another method is that of connecting a flywheel to the roller through speed-up gearing such that it shares the translation of the roller but has a proportionally higher rotational speed. In this case, the flywheel need not be larger in diameter than the roller.

A specific embodiment which may be incorporated in the overall system shown in FIG. **1** or other web handling systems is shown in FIGS. **4** through **6**. A tension regulation apparatus is there illustrated which includes a floating roller **70** resting in the bight of a downwardly depending loop **72** of web **14** which enters the loop through infeed drive assembly **30** (FIG. **1**) and exits the loop over idler roller **34**. The drive assembly is driven by the variable ratio transmission **51**.

The apparatus includes vertical mounting plates **74** attached to the framework **40** on each side of the web **14** and horizontal mounting plates **76** in the framework **40** on each side of the web. Pivotally attached to the vertical plates **78** on each side of the web are pivot arms **80** which, as illustrated, extend rightwardly from their axis of rotation **82** toward the roller **70**. Extending between the movable ends of the pivot arms is a shaft **84** to which the roller **70** is journaled on bearings **85**.

The roller loading apparatus **62** which exerts a constant force on the roller **70** and on the web **14** comprises pneumatic rolling diaphragm actuators **86** bolted on each horizontal mounting plate **76**. The actuators **86** transmit a constant force through downwardly extending connecting rods **88** to the outer end of each pivot arm **80**. The force is established by suitable adjustment of a pressure adjuster **89** at the control console. The pressure regulator supplies air at constant pressure to an air receiver or plenum **92** mounted adjacent the pneumatic actuators. Air piping **93** between the plenum and actuators is preferably large so as to further assure constancy of the force transmitted by the connecting rods **88**.

It will be apparent that in operation, as the web modulus of elasticity or the relative speed of web driving members changes while the loading force is held constant, the length of the web in the loop will gradually change and the roller will move essentially translationally, either rising or falling as such changes occur. However, it is necessary that the position of the roller be maintained within a range so that mechanical limitations on the roller's movement do not cause new forces

in the system. To achieve this, sensing apparatus **64** is provided and connected to the control console **54**. The illustrated sensing apparatus includes a light source **94** mounted on an arm **96** in a plane parallel to one of the pivot arms **80**, fixedly mounted on the same axis **82** and extending toward the roller **70**. Positioned on pivot arm **80** and vertically spaced are upper and lower light sensors **98** and **99**. The sensors are shielded from ambient sources of light by suitable means (not shown).

The sensors are so connected to the control console that when the roller approaches the bottom of its stroke, the motor drives the adjustment shaft of the variable ratio transmission in such a direction as to slow the infeed assembly, thereby decreasing the length of the web loop and causing its roller **70** to move upward. Conversely, when the roller approaches the top of its stroke, the motor is caused to run in such a direction as to increase the speed of the infeed assembly thereby increasing the length of the web within the loop and causing the roller **70** to move downward. Further, suitable error rate feedback circuits may be provided in the motor control **100** to provide faster stable response of the system.

The roller **70** comprises a central portion **108** in the form of a circular cylinder which frictionally engages the web **14** without slipping with a 180° wrap of the web therearound so that the web is tangent thereto along lines A and B. As illustrated the central portion **108** is a hollow shell with a central cylindrical cavity **110** defined by an annular wall **112**. The thickness of the wall is only so great as to with-stand the operating stresses to be expected. On each end of the central portion are identical outer portions **114** and **116** in the form of massive annuli each with an outer radius greater than the outer radius of the central portion and having most of their mass located outside the radius of that portion. The masses and distribution thereof of the components of the roller assembly **52** are chosen to satisfy equation (14), thus providing the condition for complete absorption by the roller assembly of any tension change by the roller.

It will be appreciated of course that either the masses of the annuli or their internal or external radii may be varied to provide a solution. The most desirable solution depends upon the system in which the apparatus is to be installed. In some cases, large annuli of low density may be preferred. In other cases the disks may be relatively small in diameter but quite dense. All of such variations and others which will be readily apparent are comprehended by the invention.

FIGS. **7**, **8** and **9** illustrate multiple floating roller systems, in which to achieve the desired result, it is necessary to distribute the masses of the system in such a way as to establish the lines of tangency of the incoming and outgoing webs as conjugate centers of percussion of the floating roller assembly. The floating roller assembly in this context includes the idler rollers between the incoming and the outgoing floating rollers. The mathematical description of the requirements for a multiple roller assembly is considerably more complex than that for the single roller assembly but, in general, the desired effect is achieved by adding mass to a conventional system in such a manner that the energy of the added mass depends more on the translational motion of the rollers than on their rotational motion.

Accordingly, in FIG. **7**, a multiple roller system is shown in which a plurality of floating rollers **200**, **202** and **204** are mounted for rotation about axes fixed in a carriage **206**. A web **208** passes alternately around the floating rollers and idler rollers **210**, **212** and **214** and **216** fixed on a framework **217**. The carriage is constrained to move essentially translationally. As illustrated, a mass member **218** is rigidly attached to the carriage by bolts **220**. Of course the mass member in practice could be in several separated portions.

FIG. **8** illustrates a system similar to that of FIG. **7** in which the mass member **218** is replaced by two mass members **222** and **224** attached to each end of a cable **226**. The cable is attached at **228** to the carriage **206**, and runs over a fixed pulley wheel **230**. Thus the energy of the masses in the systems of FIGS. **7** and **8** is a function of the translation of the carriage and not of the rotation of the rolls. In the system of FIG. **8** the added advantage is presented that the mass members may have masses such that the static balance of the system can be achieved.

FIG. **9** illustrates another system in which the mass member **218** is replaced by two fixed flywheels **232** and **234** mounted on wheels or sprockets **236** and **238**. The wheels or sprockets are interconnected by a cable or chain **240** which is affixed to the carriage at **242**. Thus the energy of the rotating flywheel depends upon the translational motion of the carriage. This system has the advantage that the adjustment of flywheel weights is relatively simple to accomplish in small increments. Additionally smaller total masses may be utilized to achieve the desired result.

Thus it may be seen that the present invention provides a versatile system for tension regulation which is applicable to both single and multiple floating roller arrangements and which can completely absorb transient tension changes in a moving web.

Various features of the invention are set forth in the accompanying claims.

What is claimed is:

1. Apparatus for preventing a change in the tension in one region of a moving web from causing a change in the tension in another region of said web comprising an assembly in non-slipping engagement with said web between said two regions of said web along two engagement lines extending across said web, said assembly including a rotating cylinder, means for constraining the path of said web so that said web engages said rotating cylinder over substantially 180° of its circumference, at least a part of said assembly being mounted so as to be movable translationally by force applied to said assembly at one of said engagement lines, at least a part of said assembly being mounted so as to be movable rotationally by force applied to said assembly at said one engagement line, the masses and the distribution thereof of said assembly being such that a change in force applied to said assembly at said one engagement line produces substantially no acceleration parallel to said web of said assembly at the other of said engagement lines, so that a change in web tension in one of said regions which produces a change in force on said assembly at one engagement line does not cause a change in web tension at the other of said engagement lines.

2. Apparatus for preventing a change in the tension in one region of a moving web from causing a change in the tension in another region of said web comprising an assembly in non-slipping engagement with said web between said two regions of said web along two engagement lines extending across said web, said assembly including a rotating cylinder engaging said web between said two engagement lines over substantially 180° of its circumference, at least a part of said assembly being mounted so as to be movable translationally by force applied to said assembly at one of said engagement lines, at least a part of said assembly being mounted so as to be movable rotationally by force applied to said assembly at said one engagement line, the masses and the distribution thereof of said assembly being such that conjugate centers of percussion of said assembly are substantially along said engagement lines whereby a change in force applied to said assembly at said one engagement line produces substantially no acceleration parallel to said web of said assembly at the other of said engagement lines, so that a change in web tension in one of said regions which produces a change in force on said assembly at one engagement line does not cause a change in web tension at the other of said engagement lines.

3. Apparatus for preventing a change in the tension in one region of a moving web from causing a change in the tension in another region of said web comprising an assembly in non-slipping engagement with said web between said two regions of said web, along two engagement lines extending across said web, said assembly including a rotating cylinder and at least one mass member on each end of said cylinder said mass members having substantially equal masses positioned at least

in part outside of the radius at which the cylinder contacts the web, at least a part of said assembly being mounted so as to be movable translationally by force applied to said assembly at one of said engagement lines, at least a part of said assembly being mounted so as to be movable rotationally by a force applied to said assembly at said one engagement line, the masses and the distribution thereof of said assembly being such that a change in force applied to said assembly at said engagement line produces substantially no acceleration parallel to said web of said assembly at said other engagement line, so that a change in web tension in one of said regions which produces a change in force on said assembly at one engagement line does not cause a change in web tension at the other of said engagement lines.

4. Apparatus for preventing a change in the tension in one region of a moving web from causing a change in the tension in another region of said web comprising an assembly in non-slipping engagement with said web between said two regions of said web along two engagement lines extending across said web, said assembly including a rotating cylinder and a rotating mass operatively connected to said cylinder through a gear system at least a part of said assembly being mounted so as to be movable translationally by force applied to said assembly at one of said engagement lines, at least a part of said assembly being mounted so as to be movable rotationally by a force applied to said assembly at said one engagement line, the masses and the distribution thereof of said assembly being such that a change in force applied to said assembly at said engagement line produces substantially no acceleration parallel to said web of said assembly at said other engagement line, so that a change in web tension in one of said regions which produces a change in force on said assembly at one engagement line does not cause a change in web tension at the other of said engagement lines.

5. Apparatus for preventing a change in the tension in one region of a moving web from causing a change in the tension in another region of said web comprising an assembly in non-slipping engagement with said web between said two regions of said web along two engagement lines extending across said web, said assembly including a translationally movable carriage and a plurality of rotating circular cylinders mounted on said carriage and successively engaging said web, at least a part of said assembly being mounted so as to be movable translationally by force applied to said assembly at one of said engagement lines, at least a part of said assembly being mounted so as to be movable rotationally by a force applied to said assembly at said one engagement line, the masses and the distribution thereof of said assembly being such that a change in force applied to said assembly at said engagement line produces substantially no acceleration parallel to said web of said assembly at said other engagement line, so that a change in web tension in one of said regions which produces a change in force on said assembly at one engagement line does not cause a change in web tension at the other of said engagement lines.

6. Apparatus in accordance with claim 5 wherein said assembly includes at least one mass member operatively connected to said carriage so that the energy of the added mass depends more on the translational motion of the cylinders than upon their rotational motion.

7. Apparatus in accordance with claim 5 wherein said mass member is rigidly attached to said carriage.

8. Apparatus in accordance with claim 5 including a fixed wheel, two mass members attached to the ends of a cable, said cable engaging said wheel and being attached to said carriage.

9. Apparatus in accordance with claim 5 including at least one flywheel mounted on a wheel and a cable engaging said wheel and attached to said carriage.

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