April 24, 1962 M. J. COHEN ETAL 3,031,152

IMPROVED APPARATUS FOR MEASURING, INDICATING, AND CONTROLLING WEB TENSION

Filed April 28, 1958 2 Sheets-Sheet 1

FIG. 1.

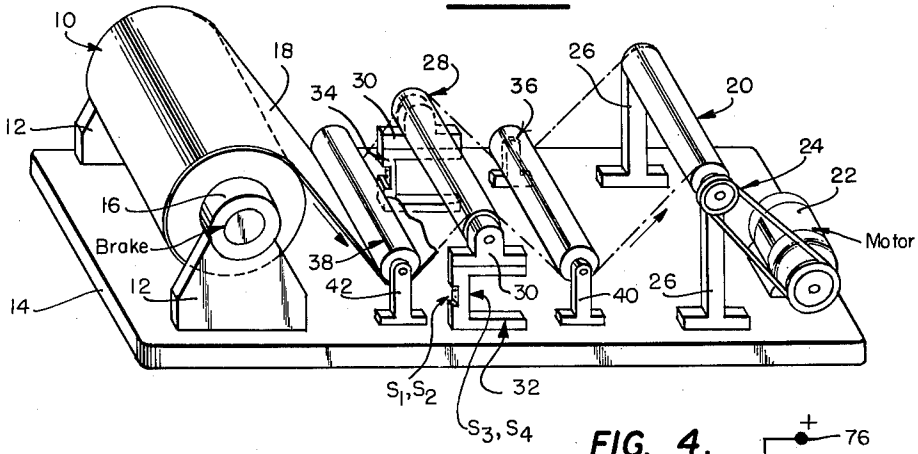


FIG. 2.

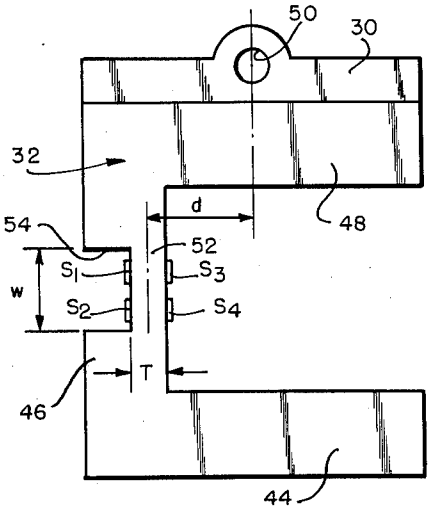
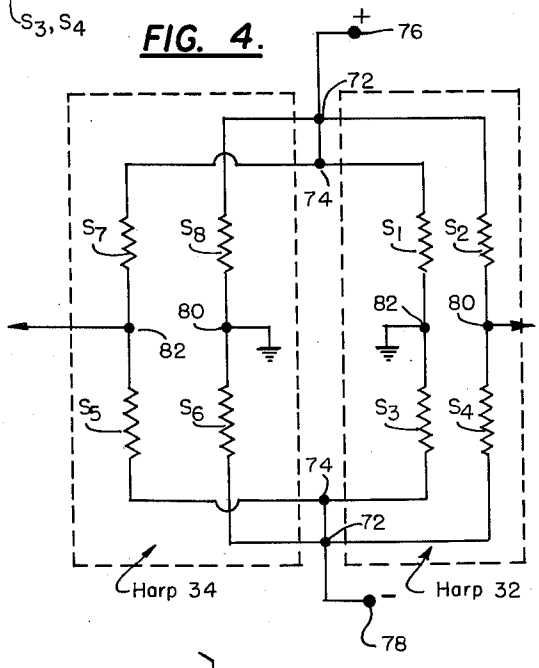


FIG. 4.



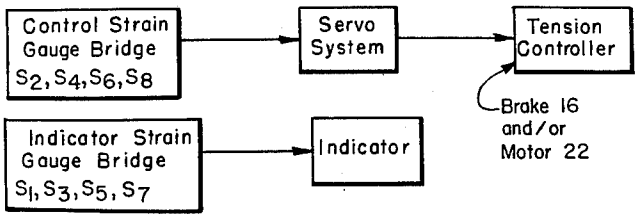


FIG. 3.

INVENTORS
Martin J. Cohen
Roger W. Young
John Dusenbery
Henry C. Gibson, Jr.

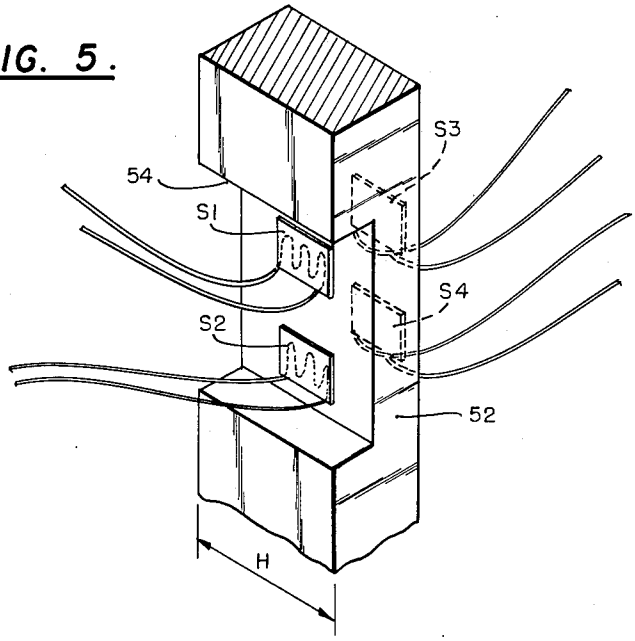
BY
Raphael Semmes
ATTORNEY

April 24, 1962 M. J. COHEN ETAL 3,031,152

IMPROVED APPARATUS FOR MEASURING, INDICATING, AND CONTROLLING WEB TENSION

Filed April 28, 1958 2 Sheets-Sheet 2

FIG. 5.



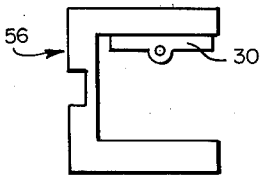


FIG. 6A.

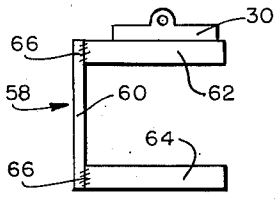


FIG. 6B.

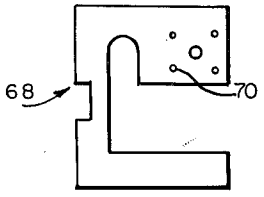


FIG. 6C.

INVENTORS
Martin J. Cohen
Roger W. Young
John Dusenbery
Henry C. Gibson, Jr.

BY
Raphael Semmes
ATTORNEY

United States Patent Office 3,031,152 Patented Apr. 24, 1962

3,031,152

IMPROVED APPARATUS FOR MEASURING, INDICATING, AND CONTROLLING WEB TENSION

Martin J. Cohen, Norristown, Pa., Roger W. Young and John Dusenbery, Montclair, N.J., and Henry C. Gibson, Jr., Palm Beach, Fla., assignors to John Dusenbery Co., Inc., Verona, N.J., a corporation of New Jersey

Filed Apr. 28, 1958, Ser. No. 731,355
11 Claims. (Cl. 242—75.51)

This invention relates to systems responsive to the tension of a moving web, as for example, a web which is being unwound from a supply roll and wound onto another roll, and more particularly is concerned with the measuring, indicating, and controlling of web tension.

Various schemes have been proposed heretofore for continuously monitoring the tension of a moving web and for maintaining the tension substantially constant. In general, some method is employed for sensing the web tension and for responsively controlling the braking force on the supply roll and/or the r.p.m. of the driving motor. A commonly used system is pneumatic, employing a "load cap" acting at one end of an idler roller. Such a system has an operating time constant of about 2 seconds, but is sufficiently responsive to measure relatively slow effects, such as the changing diameters of the rolls. It has been found, however, that due to elastic anomalies in most webs, the location of the tightest part of the web will vary across the width of the web, the remainder of the web being relatively slack. The web therefore acts tension-wise similar to a wire passing over the roller which may move rapidly back and forth across the width of the roller somewhat like a line unwound from a fishing reel. In the slow-acting systems of the type just described, such a fast movement (normally having a period of about 1 second) has little effect. However, with the higher web speeds being used today, it is necessary that the tension controlling and indicating equipment have a much faster response than the slow equipments employed heretofore, and with such response, the aforementioned phenomenon can seriously affect the operation of the system.

The present invention provides a measuring, indicating, and controlling system for web tension which has fast response but which is nevertheless substantially immune to spurious effects of the type just described, and it is accordingly a principal object of the invention to provide such an improved system.

Another object of the invention is to provide a system wherein the instantaneous web tension at points across the width of the web is averaged.

An additional object of the invention is to provide a unique system of the foregoing type wherein the effects of ambient conditions, such as temperature, are balanced out.

Still another object of the invention is to provide a system wherein the detected effects of the force of the web on a tension sensing idler roller are maximized.

The foregoing and other objects, advantages, and features of the invention and the exact manner in which the same are accomplished and provided will become more readily apparent upon consideration of the following detailed description of the invention taken in conjunction with the accompanying drawings, which illustrate preferred and exemplary forms of the invention, and wherein:

FIGURE 1 is a perspective view, somewhat diagrammatic, illustrating the application of the principles of the invention to a moving web system in which the web is wound from one roll onto another;

FIGURE 2 is a side elevation view of one form of roller support and tension sensing device of the invention;

FIGURE 3 is a block diagram illustrating the manner

in which the functions of the invention are performed;

FIGURE 4 is a schematic diagram of a preferred electrical circuit employed in the invention;

FIGURE 5 is a perspective view of a detail of the device of FIGURE 2; and

FIGURES 6A, 6B, and 6C, are alternative forms of the structure illustrated in FIGURE 2.

Briefly stated, the invention utilizes a tension sensing idler roller having strain gauges attached to special supports for the roller. These gauges are connected in an electrical circuit in such a manner that the strain effects in the supports at opposite ends of the roller are averaged, and the circuit produces outputs which are utilized to control the tension and to indicate the instantaneous value of the tension of the web. In one embodiment auxiliary idler rollers are utilized to maintain constant angles of approach to and departure from the sensing roller.

In FIGURE 1 of the drawings, the invention is illustrated as applied to a web handling system in which the web is unwound from a supply roll 10 and re-wound onto a wind-up roll 20. The supply roll may be part of a conventional roll stand having supports 12 at opposite sides of a frame 14, which is shown simply and diagrammatically. The supply roll 10 has a brake 16 arranged to apply a braking force to the roll axle and thus to resist rotation of the roll. The brake may assume any conventional form and may be electromagnetic or even a reversible variable speed motor. The web 18, which may be formed of any suitable material such as cloth or paper, passes from the supply roll 10 to the wind-up roll 20 onto which the web is re-wound. In the form shown, the wind-up roll is driven by an electric motor 22 through a pulley and belt drive generally designated 24. The wind-up roll is mounted on the frame 14 for rotary movement on supports 26 at its respective ends.

Between the supply roll 10 and the wind-up roll 20 is located an idler roller 28, which will be called the tension sensing idler roller. This roller rotates on pillow blocks 30 which are mounted on supports 32 and 34 in turn mounted on the frame 14 at the respective ends of the roller. The supports 32 and 34 will be termed harps. Additional idler rollers 36 and 38 are located on opposite sides of the tension sensing roller 28 and are rotatably supported on the frame 14 as by supports 40 and 42. The web 18 passes under idler roller 38, over sensing roller 28, and under idler roller 36. It is thus apparent that the web passes around the roller 28 in a sense opposite to its passing around rollers 36 and 38. In the form shown, roller 28 is mounted higher above the frame 14 than rollers 36 and 38, which are mounted lower than the rolls 10 and 20. It is thus apparent that when the web 18 is placed in tension, it exerts a force against the roller 28.

In a simpler form of the invention, rollers 36 and 38 may be omitted, and the sensing roller 28 may be mounted higher than rolls 10 and 20 so as to indent the straight line path of the web which otherwise would exist between rolls 10 and 20, but with such an arrangement the angle at which the web approaches and departs from the roller 28 will vary with the diameters of rolls 10 and 20. In the embodiment of FIGURE 1, these angles are maintained constant by the idler rollers 36 and 38 regardless of the diameters of the rolls 10 and 20.

Harps 32 and 34 are preferably identical, one of them being illustrated in more detail in FIGURE 2. The harp has a lower horizontal arm 44 which is attached to the frame 14, as by bolting or welding. Next there is a vertical arm 46, which will be termed the bending arm, and then another horizontal arm 48, which will be termed the cantilever arm and which extends from arm 46 and engages the pillow block 30. The pillow block has an

internal bearing surface **50** for receiving a mating bearing at the end of the roller **28**. The pillow block may be attached to the cantilever arm **48** in the same manner that the lower horizontal arm **44** is attached to the frame, or the pillow block may even be formed integrally with the harp. The arms of the harp preferably have uniform thickness except for a central portion **52** of the bending arm **46**, which is narrower. This narrower portion or waist may be provided by forming a step **54** in the arm **46** as shown.

The stress exerted on the harps by the moving web **18** produces a bending moment having a moment arm of length *d*, which is the distance between the axis of the roller **28** and a neutral bending plane which is located along the center of the waist **52** as shown in FIGURE 2. In a practical form of the invention, the moment arm *d* may be about 2 inches. The width H of the harp (see FIGURE 5) may be constant at about 1½ inches. The height *w* of the waist **52** may be about 1 inch. The harps may be formed of steel. Using C1018 steel with the foregoing dimensions and a waist thickness T of about .380 inch gives a deflection of about .002 inch for a hundred pound force on the bearing center. For higher forces, the harp can be made stiffer by increasing the dimension T, or more sensitive by reducing the dimension T. The relative dimensions of the parts shown in the drawings have been exaggerated for explanatory purposes.

By virtue of the construction shown and described, the strain produced on the harp by the stress exerted on the tension sensing roller is concentrated in the waist **52**. As long as the remainder of the harp is substantially rigid, the construction may be varied from that illustrated in FIGURE 2. FIGURES 6A, 6B, and 6C illustrate alternative forms. In FIGURE 6A, the pillow block **30** is mounted below the cantilever arm of the harp **56**, which otherwise may be substantially identical to that illustrated in FIGURE 2. In FIGURE 6B, the pillow block **30** is mounted above the cantilever arm as before, but the harp **58** is formed by welding a relatively thin plate **60** to thicker plates or bars **62** and **64** as indicated at **66**. In FIGURE 6C, the separate pillow block is eliminated, and the harp **68** has its cantilever arm formed integrally with a depending bearing block **70**.

In accordance with the principles of the invention, the strain produced on the harps **32** and **34** is detected by strain gauges which are attached to the waist **52** of the harps. In the form shown, four strain gauges are attached to each harp as shown in FIGURE 5. The gauges attached to harp **32** are designated **S1**, **S2**, **S3**, and **S4**, and the gauges attached to the other harp **34** will be designated in corresponding position **S5**, **S6**, **S7**, and **S8**. The strain gauges are of conventional type, such as the type described in U.S. Letters Patent 2,316,203 to E. E. Simmons, Jr., and are preferably of the type having a sinuous wire the resistance of which varies with elongation and contraction. The active wire elements are normally held within an insulating sandwich which may be cemented to the harps. In some instances, the wires may be deposited directly on their bending arm supports. By mounting the strain gauges on the thin waist of the harp, maximum sensitivity is obtained, since the strain is concentrated in these sections. It will be noted that the strain gauges **S3** and **S4** and their counterparts **S7** and **S8** on the other harp are mounted on the side of the neutral bending plane opposite the mounting of the strain gauges **S1** and **S2** and their counterparts **S5** and **S6** on the other harp. It will be apparent, therefore, that the strain gauges on one side of the bending plane will be affected oppositely with respect to the strain gauges on the other side, and for any given stress exerted on the cantilever arm of a harp, the gauges on one side will have their resistance increased, while the gauges on the other side will have their resistance decreased. A differential change in resistance is therefore obtainable.

In accordance with the invention, the strain gauges form variable resistance branches of a pair of electrical bridge circuits, which are illustrated in FIGURE 4. These bridges are designated the control bridge and the indicator bridge, respectively. The control bridge comprises strain gauges **S2**, **S4**, **S6**, and **S8**, while the indicator bridge comprises strain gauges **S1**, **S3**, **S5**, and **S7**. Each bridge has two pairs of conjugate terminals, one pair of terminals, **72**, of the control bridge, and the corresponding pair of terminals, **74**, of the indicator bridge are connected across a voltage supply, which in the form shown is a D.C. supply having opposite poles **76** and **78**. The remaining terminals **80** of the control bridge and **82** of the indicator bridge are utilized as output terminals, and the output circuits comprise lead wires attached to these terminals. One terminal **80** and one terminal **82** may be grounded as shown. It will be seen that each supply terminal is connected between gauges on different harps, and each output terminal is connected between gauges on the same harp.

Before the operation of the bridge circuits is described in detail, it is well to note the overall systems associated with the circuits. As shown in FIGURE 3, the control strain gauge bridge has its output connected preferably to a servo system, the output of which is connected to a suitable tension controller. The servo system may be of conventional form, including amplifiers and servo transmitters and receivers as required, and the tension controller may be the brake **16** of FIGURE 1 or the motor **22** or both. In an illustrative system, the servo system has an electrical output which controls the braking force so as to maintain the web tension constant. Since it is the tension which affects the control strain gauge bridge, it will be apparent that this bridge, its servo system and the tension controller are part of a feedback loop.

While an indicator might be provided in the control system to indicate the instantaneous value of the web tension, it is preferred to provide a separate indicator system, and the indicator strain gauge bridge is utilized for this purpose. The output of this bridge may be applied to any suitable type of meter or indicator, and if desired, this system may include suitable amplifiers and recording equipment.

A primary purpose of the invention is to provide a web tension control system having high sensitivity and short response time. For this purpose, it is essential that the tension detecting means operate substantially instantaneously. Detecting means having such fast response are greatly affected by the phenomenon previously described whereby the point of maximum tension shifts back and forth across the width of the web. The present invention overcomes the spurious effects produced by this phenomenon by averaging the outputs from the strain gauges on the respective harps.

Considering the indicator bridge as typical of both bridge circuits, it will be observed that strain gauges **S1** and **S3** have differential resistance variations (since they are on opposite sides of the neutral bending plane), and that the same is true of strain gauges **S5** and **S7**. Neglecting for the moment theeffect of the shifting of the point of maximum web tension, for a given web tension there will be a given stress applied to each of the harps **32** and **34**, and these stresses will be of equal magnitude assuming that the web tension is uniform across the web. A bending moment will thus be applied to the waist **52** of each harp. Strain gauge **S1** will be subjected to elongation, while strain gauge **S3** will be subjected to contraction. Similarly strain gauge **S5** will be subjected to elongation and strain gauge **S7** to contraction. Accordingly, the resistance of gauges **S1** and **S5** will be affected in one sense, and the resistance of gauges **S3** and **S7** will be affected in the opposite sense. Since the potential at the respective terminals **82** will vary oppositely as a result of the resistance changes, there will be a difference of potential between the terminals.

Assuming now, that instead of uniform tension at all

points across the web or location of the point of maximum tension at the center of the web, the point of maximum tension shifts, say toward harp **32**. The stress on harp **32** will then be greater than that on harp **34**, and while strain gauges S1 and S3 will be affected even more greatly in the same manner as before, the stress on gauges S5 and S7 will decrease. Thus while gauge S1 will be subjected to greater elongation, gauge S5 will be subjected to less elongation, and while gauge S3 will be subjected to greater contraction, gauge S7 will be subjected to less contraction. The lesser contraction of gauge S7 is the equivalent of elongation, and the lesser elongation of gauge S7 is the equivalent of contraction. Therefore, the resistance of gauges S1 and S7 will be affected in one sense and the resistance of gauges S3 and S5 will be affected the opposite sense. The result is that the potentials of the respective output terminals **82** vary in the same direction and the difference in potential across the terminals does not vary. The same type of explanation applies if the point of maximum tension moves toward harp **34**, rather than toward harp **32**, and as long as the average instantaneous tension remains the same, the output of the bridge will not vary.

The bridge circuit thus provides a means for producing an output which is representative of the average of the instantaneous web tension at points across the web. Moreover, the use of a bridge circuit renders the system substantially insensitive to the spurious effects of ambient temperature changes, for example, since the temperature will affect all of the strain gauges in the same manner, and the bridge output will be unaffected. A system of the type illustrated in FIGURE 1 may be calibrated relatively simply, for the idler rollers **36** and **38** maintain constant the web angle of approach to and departure from roller **28**.

From the foregoing description of the invention, it will be appreciated by those skilled in the art that a simple yet highly effective system is provided for measuring and controlling web tension. While preferred embodiments of the invention have been shown and described, it will be apparent that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the appended claims. Accordingly, the foregoing embodiments are to be considered as illustrative, rather than restrictive of the invention, and those modifications which come within the meaning and range of equivalency of the claims are to be included therein.

We claim:

1. In a system in which a web is fed from a supply roll to a wind-up roll, a tension sensing roller located along said web between said rolls, idler rollers located between said sensing roller and said rolls, respectively, said web passing around said sensing roller in a sense opposite to its passing around said idler rollers, said sensing roller being mounted on supports at each of its ends, each said supports having a bending arm and a cantilever arm extending therefrom to mount said sensing roller, said bending arms having variable resistance strain gauges attached to opposite sides thereof located to be affected oppositely by stresses applied to said cantilever arm, said gauges being connected as the four branches of a bridge circuit, said bridge circuit having a voltage supply and an output circuit connected, respectively, across conjugate pairs of bridge terminals, with each of the supply terminals connected between gauges on different supports and each of the output terminals connected between gauges on the same support, and means connected to said output circuit for applying a variable tensile force to said web.

2. The system of claim 1, further comprising four other variable resistance strain gauges attached to said supports in corresponding relation to the aforesaid gauges, the other gauges being connected in another bridge circuit like the first and having an indicator connected to its output circuit.

3. In a system of the type described, a supply roll from which a web is fed, a web tension sensing roller located along said web and against which said web passes, an idler roller against which said web passes at a location between said roll and said sensing roller, whereby the angle of approach of said web to said sensing roller may be kept constant regardless of the roll diameter, supports for each end of said sensing roller, strain gauge means attached to said supports for measuring the strain of said supports in response to stress exerted thereon by said web, and means for averaging the instantaneous measurements by said measuring means.

4. The system of claim 3, further including a roll onto which said web is wound, and another idler roller between said sensing roller and the last-mentioned roll to maintain a constant angle of departure of said web from said sensing roller regardless of the diameter of the last-mentioned roll.

5. In a system for controlling the tension of a moving web, a roller against which said web passes, said roller having a support at each of its ends, each of said supports having strain gauge means attached thereto for detecting strain of the associated support in response to stresses exerted thereon by said web and for producing an output signal, means for producing a signal representative of the sum of the output signals associated with the respective supports, and means for applying a variable tensile force to said web along its length in response to said sum signal.

6. The system of claim 5, said force applying means comprising a motor drive for pulling said web.

7. The system of claim 5, said force applying means comprising a brake for resisting the movement of said web.

8. The system of claim 5, further comprising means responsive to said sum signal for indicating the web tension.

9. The system of claim 5, said supports comprising bending arms, and said strain gauge means comprising strain gauges attached to said bending arms.

10. The system of claim 9, said bending arms having portions of maximum strain at which said gauges are located.

11. The system of claim 9, each support having a pair of gauges located so as to be affected oppositely by the strain of the associated support.

References Cited in the file of this patent

UNITED STATES PATENTS

1,286,331	James	Dec. 3, 1918
1,343,910	Evans	June 22, 1920
2,100,653	Umansky	Nov. 30, 1937
2,444,245	Campbell	June 29, 1948
2,586,412	Winchester	Feb. 19, 1952
2,659,154	Rendel	Nov. 17, 1953
2,680,376	Shaw et al.	June 8, 1954
2,809,519	Kaestner	Oct. 15, 1957
2,833,145	McCullough	May 6, 1958
2,927,458	Moon et al.	Mar. 8, 1960