June 28, 1966 J. D. BOADWAY ETAL 3,257,734

METHOD FOR CONTROLLING TENSION IN SUPPORTED SHEET MATERIAL

Filed Sept. 29, 1965 3 Sheets-Sheet 1

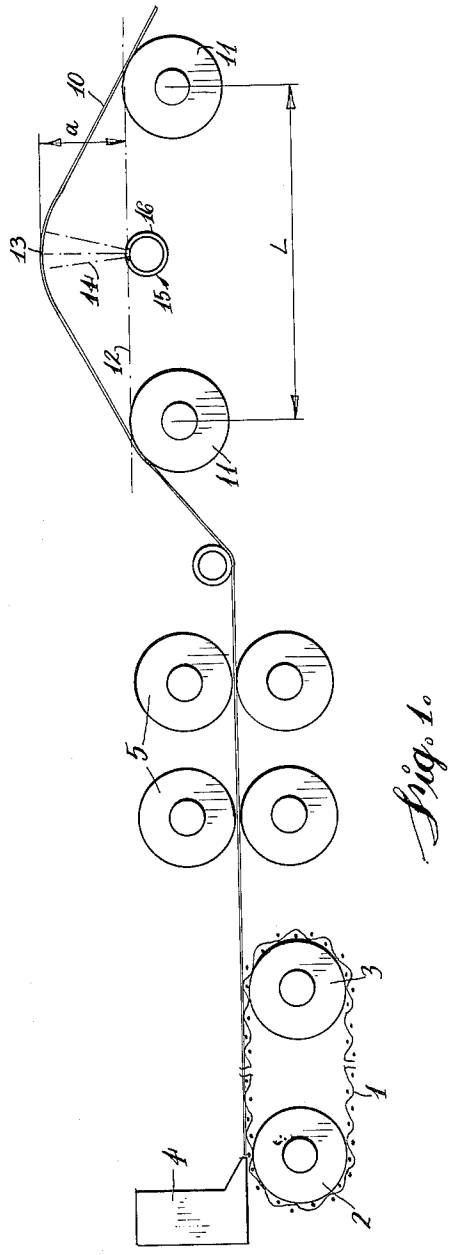


Fig. 1.

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Filed Sept. 29, 1965 3 Sheets-Sheet 2

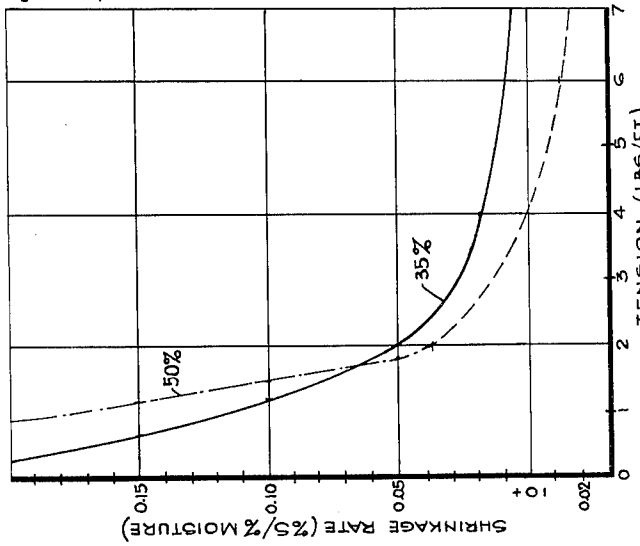


Fig. 4.

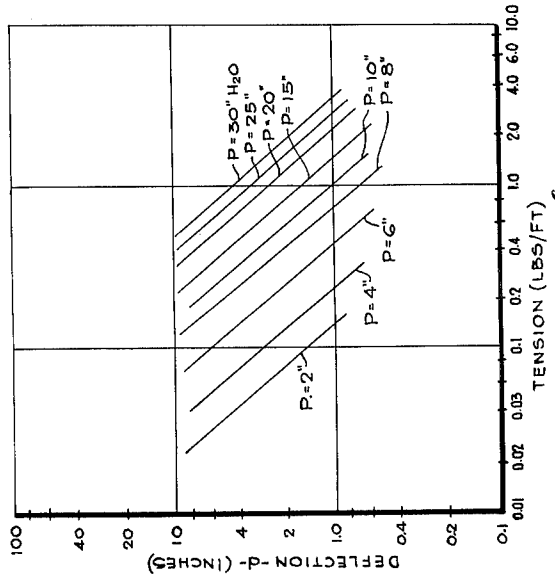


Fig. 3.

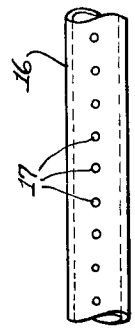


Fig. 2.

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METHOD FOR CONTROLLING TENSION IN SUPPORTED SHEET MATERIAL

Filed Sept. 29, 1965 3 Sheets-Sheet 3

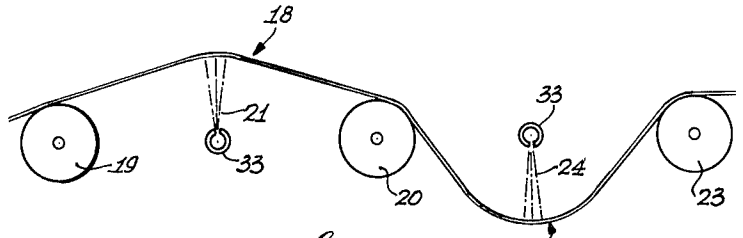


Fig. 5.

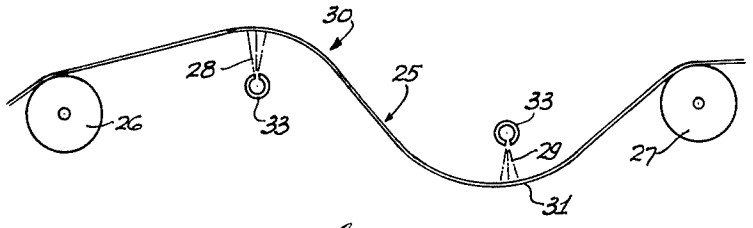


Fig. 6.

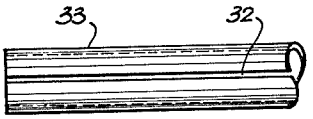


Fig. 7.

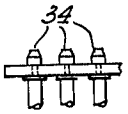


Fig. 8.

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METHOD FOR CONTROLLING TENSION IN SUPPORTED SHEET MATERIAL

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Filed Sept. 29, 1965, Ser. No. 491,360
4 Claims. (Cl. 34—18)

This invention relates to a method for controlling shrinkage in a paper web during the drying stage in paper manufacture. This application is a continuation-in-part of application, Serial No. 227,010, filed September 28, 1962.

It is known that if paper is allowed to shrink freely while drying certain desirable properties are imparted to the paper.

A paper web, after wet pressing and as it enters the dry end of the paper machine, has a moisture content of approximately 65%. If the web is unrestrained as it dries to a moisture content of 45%, it will shrink very little. However, on drying from 45 to 9% moisture, the web may shrink as much as 12%.

A sheet, which is allowed to shrink while drying will, after drying, exhibit stretchability or elongation before rupture of as much as 15%. On the other hand, the stretchability of a similar sheet dried under restriction and tension, may be as low as 2%.

It is well recognized that a paper of substantial stretchability or extensibility possesses advantages. For example, stretchability allows the paper to withstand impact forces to a higher degree. It also permits papers, such as wrapping papers, to conform to the shape of the object which it carries, thus distributing the load and minmizing breakage. Therefore, there is an advantage in allowing the paper to shrink during at least a part of the drying procedure thereby to impart a high degree of stretchability to the paper.

The conventional drying procedures are not readily adaptable to accomplishment of this shrinking during drying. This is mainly due to the manner in which the drying cylinders are driven and the manner in which the paper is transported through the drying section of the paper machine. These conventional procedures are such that the paper web does not have the opportunity to shrink but rather is continually subjected to a tension or draw which tends to adversely affect the stress-strain characteristics of the paper.

The amount of shrinkage involved, however, is generally small by the time this is spread over a large number of drying cylinders, so that the percentage speed change between consecutive cylinders becomes exceedingly small. To affect and control this shrinkage, the drying mechanism for these dryers would, therefore, need to control an extremely small differential between the dryers. Furthermore, web tension must always be maintained close to zero so as to permit a uniform shrinkage to take place; this means, that little or no variation in this differential can be tolerated.

A mechanical system of gears would be too crude to handle such a requirement. In the case of using electric drives on the individual dryers and controlling electronically the required differential speed between the dryers, an error generally has to exist before the electronic circuitry will make a correcting adjustment. This creates a temporary fluctuation which is in itself corrected for by an over-compensating adjustment so as to maintain the correct average condition. All this then gives rise to fluctuations of a cyclic nature. Since a tensionless web can lead to web wrinkling and wandering, the minimum allowable tension should be close to zero tension; however, because of these cycles, a mean tension is maintained which is considerably above zero. As mentioned above, this is undesirable from a paper quality point of view.

It is an object of this invention to provide a method for drying a paper web whereby shrinkage thereof may be substantially and accurately controlled and desirable characteristics thereby imparted to the final paper product.

One manner of controlling tension in a travelling paper web would be to store one or more lengths thereof at very low tensions between a pair of the drier rolls, whereby short term differential speed variations could be absorbed without creating large changes in tension. It will be apparent that this storage may be effected by some form of web take-up. One possibility would be the deflection or diversion of the web from the straight path between the pair of rolls by means of a take-up roll which would be lightly loaded in order to maintain a light tension. A major drawback of such a means, however, would be that such a take-up roll would, because of its inertia, resist sudden changes in position which it would need to do so as to follow the short term variations in differential speed.

The present invention contemplates deflecting a paper web from its normal straight line path between two supporting drying cylinders or rolls and maintaining such web in a state of tension, by means of a fluid jet. In accordance with the invention, such a fluid jet provides a force sufficient to create a deflection in the web, which deflection creates a slight tension in the web. The greater the distance of deflection of the web, the greater is the length of web stored between the two transport points. Thus, with fluctuations in the differential speed between the two points, there will be a fluctuation in web deflection, but only minor fluctuations in the web tension.

The invention will be described with reference to the accompanying drawings, in which

FIGURE 1 is a side elevation, partly in diagrammatic form, of an apparatus in accordance with the invention,

FIGURE 2 is a partial plan view of a jet forming device,

FIGURE 3 is a graph indicating the type of relationship existing between the deflection and the web tension for various fluid pressures,

FIGURE 4 is a graph showing the relationship between shrinkage in a paper web for a given loss in moisture and paper tension,

FIGURES 5 and 6 are diagrammatic side elevations of modified forms of apparatus, and

FIGURES 7 and 8 are plan views of alternative forms of jet producing devices.

Referring to FIGURES 1 and 2, **10** is a wet paper web travelling over a pair of drier rolls or cylinders **11**. The web has been formed in conventional manner on a Fourdrinier wire **1** supported on breast roll **2**, and couch roll **3**, and fed with stock from head box **4**. Standard presses **5** may be provided. The normal straight line path of the web between the cylinders **11** is indicated at **12**.

In accordance with the invention, the portion **13** of the web between the cylinders is deflected as shown by means of a fluid jet **14** produced by a jet forming device **15** which may comprise a pipe **16** supplied with fluid, such as air, under pressure, and having a row of openings **17** therein.

The jet force may be roughly estimated at PA per unit width where P is the fluid pressure and A is the area of the jet opening or openings per unit width. The variation of the jet force with respect to distance from the point of issuance is complex. Up to a distance of 12 inches, this force has been found to be approximately constant.

The force from the jet acts against the sheet which gives rise to a tension (t) in the web. It will be apparent that this tension (t) has a component which acts directly against the jet force (PA) and this component is equal to $t \sin \theta$. Since there are two such components each acting on an opposite side of the jet, then

(1) $$PA = 2\ (t \sin \theta)$$

For small angles of θ we can let

$$\sin \approx \frac{d}{L/2} = \frac{2d}{L}$$

and

$$PA = 2t\frac{2d}{L}$$

(2) Therefore:

$$t = \frac{PAL}{4d}$$

where

P=air pressure per unit area
L=length of span between transport points
A=jet opening area per unit width
d=deflection of web
t=web tension per unit width

Practical experiments have indicated that the relationship is:

(3) $$t = \frac{PAL}{4{:}43\ d\ 0.845}$$

the units employed being pounds and inches.

By way of example, in a typical design for a paper machine 12 feet wide, 500 cubic feet per minute of air would be supplied at a pressure of 10 inches of water to a 4 inch diameter pipe **16** running across the machine and having a single row of ⅛ inch diameter holes **17** therein ½ inch apart.

Thus, for a straight line span of 40 inches, air issuing from such a row of holes under the above conditions would deflect a web of paper approximately 4 inches and the tension in the web would be in the order of 0.3 pound per foot of width. This deflection is equivalent to a storage of approximately 0.8 inch of paper. FIGURE 2 illustrates the experimental relationship between t and d for other air pressures (P).

In the case of a paper machine operating at 1000 feet per minute, its drive is capable of causing a speed variation of 0.1%, the maximum duration of which would be in the order of 2 seconds. Under these conditions, the sheet deflection would alter from 4 inches to 2¾ inches in the case of an increase in tension and 4 to 5 inches in the case of a decrease in tension (i.e., increase in slackness); the tension changes corresponding to these deflections would be from 0.3 to 0.44 and 0.3 to 0.25 lb. per linear foot respectively. On the other hand, if the web with straight transfer is to be kept under sufficient tension so that a 1/10 of a percent change in draw would not produce slack paper it would have to be kept at a tension of, say, at least 5 lbs. per foot of width with a tension varying up to 20 lbs. per foot of width. Such tensions would prevent or hinder any shrinkage of the web as it dried.

The present invention is thus capable of providing storage of relatively short lengths of paper web which can be made smoothly available as required to compensate for short term fluctuations in the difference in speed between successive dryers. This storage, including the range that it might fluctuate in an effort to compensate for these speed variations, is under conditions of low web tension (very much lower than those presently used) and this tension is in a range which will allow the paper to shrink quite freely (see FIGURE 4, top part of curves) and thus improve the final properties of the paper. The invention

makes it possible to maintain a tension which is as low as possible while avoiding the region of zero tension where wrinkling of the web may take place. Present practice not only prevents shrinkage of the paper but rather stretches it, with resultant loss in certain strength properties (see FIGURE 4, lower part of curves).

A further advantage of the invention will become apparent by examination of FIGURE 4. Since it is possible to operate at a very low tension, a greater elongation potential is now available as an additional last resort compensation for speed variations. This provides an increase in the safety factor in terms of paper rupture. The deflection feature (plus the remaining shrinkage potential) is capable of compensating for increased web slackness. Also to be noted is the self-adjusting feature of the inter-action between the shrinkage and the decreasing tension with increasing deflection. That is, as the deflection (d) increases in an effort to take up slack, the tension (t) decreases (since it is a function of the angle θ, or d-Equations 1 and 2 above), and this allows more shrinkage to take place and itself take up some of the slack.

While this invention is very useful in absorbing short term drive fluctuations, it is somewhat limited in its ability to absorb long term variations or a slight drive maladjustment. This would be particularly true for webs where very small dimensional changes in the width are accompanied by large tension changes, for in this case, the paper stored by this deflection technique would be rapidly consumed. However, the invention has another feature which allows it to be used as an indicating or control device which can be used to control more effectively the guiding mechanisms which originated the long term variation. Equation 3 indicates an empirical relationship existing between the deflection (d) and the web tension (t). As mentioned above, this has been plotted in FIGURE 3 for various air pressures P. Since the position of the web is dependent on web tension, and since its position can be detected by various known means (e.g., light beams, mechanical devices) the signals from the positioners can then be used to regulate the differential speed of controls of the web transport means. Thus, these troublesome long term variations can be ironed out leaving the remaining deflection of the web to smooth out the short term variations for which it is well suited. Where it is not necessary to employ this control device, the web position detector might still serve as a simple indicator of web tension.

It will be apparent that the fluid jet employed to deflect the web could at the same time be used for any desirable processing of the web such as, for instance, in the drying, heating or chemical treatment of it. To ensure uniform processing, it may be desirable to allow the jet to impinge alternately on opposite sides of the web. In its application to the drying of paper, this may readily be effected, as shown in FIGURE 5, wherein the portion **18** of the web between a pair of dryers **19** and **20** is subjected on one side to the action of jet **21** and the succeeding web portion **22** between the pair of dryers **20** and **23** is subjected on the other side of the action of a jet **24**.

It should be observed that a jet of, for instance, air, would result in other effects in addition to drying. Thus, the drying phenomena could be accompanied by a cooling effect resulting from the evaporation of water in the web, and this in turn would induce further shrinkage of the web which would further enhance the properties of the final paper.

FIGURE 6 illustrates another modification of the invention wherein the web **25** between two drier rolls **26** and **27** is subjected to a jet **28** and a succeeding jet **29** on the opposite side of the web whereby zigzag deflections **30** and **31** are produced. This results in additional storage of the web.

It will be obvious that the jet forming device may take a wide variety of forms. Instead of a row of holes in a pipe, as shown in FIGURE 2, a single continuous slot

32 may be provided in a pipe or like header 33, as shown in FIGURE 7. Another alternative means is shown in FIGURE 8, wherein a row of separate nozzles 34 are provided. It will be understood, however, that the word "jet" as employed in this specification and appended claims, is intended to include a jet formed by means of a continuous jet opening extending from side to side of the web or one formed by means of a series of jet openings arranged in a row.

The type of fluid employed to create the jet will vary in accordance with surrounding circumstances. Generally speaking, the fluid will be gaseous. Air is a logical choice and would fulfill many conditions of use, particularly since compressed air is readily available and relatively inexpensive to supply. Steam may be employed. Other gases, depending upon the need for chemical treatment of the web, may be employed. In other instances, a liquid jet of, say, water, may be employed. A liquid jet containing a coating composition or other chemical composition may be employed.

We claim:

1. A method of manufacturing paper which comprises forming a wet paper web on a fourdrinier wire from pulp stock, directing said wet web onto a pair of driven dryer cylinders, drying said web by engagement with said cylinders while applying continuous travelling movement to said web by driving said cylinders, each said cylinder having fluctuations in the speed thereof differing from those of the other said cylinder, said web normally assuming a substantially straight line path between said cylinders, and reducing the fluctuations in tension of said web as a result of said differential cylinder speed fluctuations by applying a gaseous jet from an elongated jet opening zone to one surface of said web between said cylinders and extending transversely from edge to edge of said web to deflect from said straight line path a length of said web between said cylinders, and controlling the extent of deflection of said deflected length to compensate for said differential cylinder speed fluctuations.

2. A method of manufacturing paper as defined in claim 1, wherein the extent of said deflection of said web is controlled in accordance with the formula

$$t=\frac{PAL}{4d}$$

where t is web tension per unit length, P is gas pressure per unit area, L is the length of the web between said cylinders, A is the area of said jet opening zone per unit width, and d is the extent of deflection of said web.

3. A method of manufacturing paper which comprises forming a wet paper web on a fourdinier wire from a pulp stock, directing said web onto a plurality of driven dryer cylinders, drying said web by engagement with said cylinders while applying continuous travelling movement to said web by driving said cylinders, each said cylinder having fluctuations in the speed thereof differing from those of the other of said cylinders, said web normally assuming a substantially straight line path between each pair of successive cylinders, and reducing the fluctuations in tension of said web as a result of said differential cylinder speed fluctuations by applying a gaseous jet from an elongated jet opening zone to at least one surface of said web between each pair of successive cylinders and extending transversely from edge to edge of said web to deflect from said straight line path a length of said web between each said pair of cylinders and controlling the extent of deflection of said deflected length to compensate for said differential cylinder speed fluctuations.

4. A method of manufacturing paper as defined in claim 3, including the step of applying a gaseous jet to each surface of said web, said jets being applied to spaced portions of said web whereby said web is deflected in opposite directions from said straight line path.

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