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The Effect of a Sheet Tension Controller on the Productivity of a Papermachine

Timothy J. Rummel
Western Michigan University, trummel4@yahoo.com

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CERTIFICATE OF ORAL EXAMINATION

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Dewei Qi

Dr. Dewei Qi
Paper and Printing Science and Engineering

Raja Aravamuthan

Dr. Raja Aravamuthan
Paper and Printing Science and Engineering

The Effect of a Sheet Tension Controller on the Productivity of a Papermachine

by

Timothy J. Rummel

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ABSTRACT

This thesis proposal outlines a project in which the efficiency of a papermachine is increased by controlling the tension through the dryer section. The controlled tension is expected to reduce wet end breaks and to decrease the steam demand of the dryer section. The experiment will be run by placing a laser positioning sensor above the open draw of a papermachine and monitoring the position of the draw until an optimum height of the paper has been determined. Then an automatic drive controller will be connected to the wet end drive to maintain a constant draw height and the machine performance at this point will be evaluated. A theory will be developed that concerns the thin insulating layer of air between the sheet and the dryer can. The amount of tension required to operate the machine at the most efficient level will also be determined.

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CHAPTER

PROBLEM STATEMENT

This thesis is proposed to create an efficient and cost effective method of optimizing the speed differential that commonly exists between the wet and the dry ends of the paper machine. The results of this project are to indicate that a control system can be used to keep the draw at an optimum tension level that would lower drying costs and reduce breaks while not tightening the draw so much as to break the paper. A laser positioning sensor fixed above the machine is the proposed method of monitoring the draw tension. Once the position sensor is operational, the optimum height of the paper in the draw will be determined and a control system will be used to alter the wet end drive speed to keep the draw at a uniform tension.

GOALS

It is the intent of this project to have a laser sensor installed over the draw of a papermachine between the wet and dry ends. This signal from this device is then to be linked to a computer controller which is capable of adjusting the draw tension accordingly to keep it at some level which has been determined to be an optimal level for the papermachine. Then energy consumption and break occurrence before and after the installation are to be compared. It is the goal of this project to find that such a capital investment could provide a mill with substantial energy savings and reduced downtime from fewer breaks.

OBJECTIVES

The objectives of this project are to determine that the proposed system in this experiment will greatly increase the cost effectiveness of the dryer section of a papermachine. The average steam consumption of the dryer section of a paper machine before installation is to be determined and compared to the consumption of the machine with the system fully operational. The frequency of breaks is to be considered in the same manner. It is expected that the device will greatly increase the runnability of the papermachine and reduce the operation costs.

BACKGROUND

Air Systems of Dryer Sections

The movement of air within a dryer section is crucial to the efficiency of a paper machine. Generally, 100 tons of air are used to make one ton of paper (1). Also, it costs roughly seven times as much to remove water with steam in the dryer section as it does to remove it with a press (2). Therefore the air movement around the dryer cans is important to controlling costs.

To prevent needless loss of energy, closed hoods are placed around most dryers to keep the heated air around the paper (3). The driving force for heat transfer to the web is the temperature difference between the paper and the air (1). Consequently, the driving force for mass transfer is the humidity difference between the air and the paper (1). Therefore, an optimization between exhausting or recycling the air is needed.

Higher air velocity through the dryer section across the web increases drying efficiency (1). Because of this there are several techniques for increasing the flowrate through the dryer section. Two of these innovations which are relevant to this discussion are open fabrics and pocket ventilation systems (3). The purpose of a pocket ventilation system is to promote evaporation by decreasing the amount of stagnant air around the felt and the web (1). Pocket ventilation increases the velocity of air where the paper is contacting or leaving the surface of the drum most significantly (3). This can increase the air pressure at the contact point which contributes to the entrainment of air between the dryer can surface and the paper or felt. Although this does not negate the cost effectiveness of pocket ventilation systems, it is important to the upcoming discussion of the stagnant layer of air around the dryer drum.

Concerning the layer of air under the sheet or felt, the development of open mesh fabrics is more important. These felts allow air to flow through the fabric instead of being held between the felt and the drum. The air pressure around the point where the felt contacts the drum causes a pumping action in and out of the pocket because the pressure differences push air through the fabric. This achieves ventilation by allowing air in and out of the pockets. (3)

These are only a few of the systems which can affect air entrainment against the drum. In any modern paper machine operating at speeds greater than a few hundred feet per minute, the air layer will be present, although the thickness of the layer is highly variable (4). It is the thickness of this layer which is so important to the efficiency of the dryer section. A discussion of heat transfer will show how this is the case.

Effect of Air Entrainment on Heat Transfer

Air is an excellent insulator against the movement of heat (5). As heat flows from the steam in the dryer to the paper, it must pass through condensate, scale, the dryer shell, and a layer of entrained air (4). Of each of these layers, the air is the most insulating per unit of thickness (4). Heat transfer can be represented by the equation that follows (5).

$$Q = U \quad A \quad \Delta T$$

where Q = heat transfer rate
A = area of heat transfer
ΔT = temperature difference
U = overall heat transfer coeff.

Because *Q* is proportional to *U*, it can be said that decreasing the coefficient of heat transfer decreases the heat transfer. Since increasing the thickness of the layer of air will decrease *U*, the direct importance of the thickness of the layer of entrained air on dryer efficiency has been shown. (5)

Effect of Tension on Thickness of Entrained Air Layer

By maintaining adequate sheet or felt tension, the thickness of the layer of air is reduced (6). The only other ways that the amount of entrained air on a typical paper machine can be lessened are for the air to escape through the sheet or out of the edges of the machine (6). For most modern machines these are impractical.

For machines where a numerical reading of the loading on the felt is available, there are several convenient rules to follow, many of which have been published by TAPPI. The recommended felt tension is directly proportional to the machine speed and varies with cylinder diameter to the 1.5 power (4). A common felt loading is ten pounds per linear inch to keep the air gap at a thickness of two or three thousandths of an inch, which is a fairly good value for efficient heat transfer (6).

There are also several general rules for felt or sheet tension which are important to a discussion on tension control. For machines with more than one dryer felt, efficiency increases come primarily from tightening the first felt as opposed to one closer to the end of the machine (7). There is also an optimum level of tension at which continued tightening produces no further efficiency increases (7). For machines that operate at speeds below 100 feet per minute, the effects of tension control on machine efficiency are negligible (8). Also, increases in machine speed should be counteracted with tension.

The layer of entrained air is created mostly because the point at which the sheet, the felt, and the drum surface converge has a pressure build up from stagnant layers of air being forced into a wedge. This compacting of air creates roughly 0.10 psi of air pressure. The air is trapped in most circumstances except for negligible losses from the edge of the sheet. The pressure is then about the same at the end of the contact zone. At this point, just before the paper separates from the drum, a slight pressure pulse occurs. This is only about a 0.02 psi increase. This occurs because the retained air, which is moving at the same speed as the sheet, contacts the air in the pocket which is slower moving or moving in different directions because of pocket ventilation. (6)

Effect of Draw Displacement on Tension

For older or smaller machines, or for board machines with no dryer felts, rules relating machine efficiency to felt loading or operating speeds have little useful purpose. For these machines an alternative method of measuring the sheet tension is necessary. This can be determined by studying the parabolic curve that the sheet forms between the wet and dry ends of the machine, or the 'dip' in the sheet between the two rolls (9).

The paper can be thought of as a cable strung between two poles, which forms a parabola. The distance between the two poles can vary, and will be referred to as the variable *l*. No matter how hard either end of the cable is pulled, it will always dip in the middle (10). This 'sag' can be quantified by referring to the dip as the distance between the center of the cable and the exact center of an imaginary line drawn between the two points where the cables meet the poles. This variable will be called *d* and should be in the same units of length as *l* (9). These parameters are shown below in Figure 1.

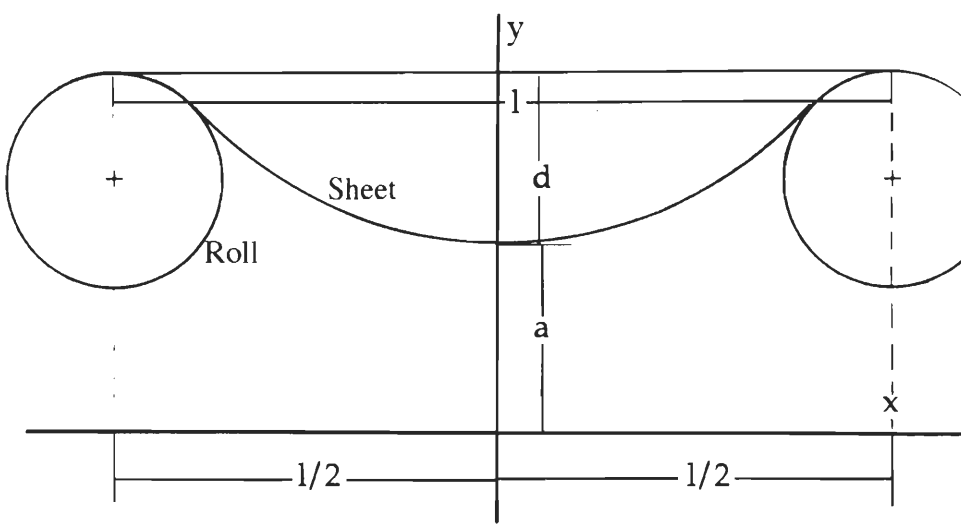

Figure 1: Illustration of a Papermachine Draw

The basic equation of the parabola in Figure 1 follows.

$$y = a \cosh (x/a)$$

The x and y in this equation are mathematical coordinates of the parabola, and a is a factor which decreases the amount of dip as its value increases. The y-intercept also equals a. Through a series of substitutions these mathematical components can be related to the factors of the sheet position on the machine which are shown in Figure 1.

If the dip is less than 10% of the span length, which it will be on a normal machine, the equation can be approximated as shown below (9).

$$y = a(1 + (x^2/2a^2))$$

and then $$y = a + (x^2/2a)$$

With some cancellations this takes the form of the basic equation for a parabola, $y = x^2$. Now the complete equation must be related to the sheet parameters shown in Figure 1. Because x and y can be infinitely large, limits must be placed on them. Coordinates x and y can be related to l and d, respectively, as is shown in Figure 1. These are related by a, which is the factor from the original equation that determined the shape of the parabola. The equations relating the variables shown in Figure 1 are given below. (9)

$$y = d + a \qquad \text{and} \qquad x = l/2$$

These can then be substituted into the previous equation, $y = a+(x^2/2a)$, and simplified.

$$d + a = a + ((l/2)^2/2a)$$

then $$d = l^2/8a = x^2/2a$$

or $$a = l^2/8d = x^2/2d$$

These equations can then be combined to give another equation which does not contain the factor *a*.

$$y = d + l^2/8d$$

Tension is related to the y parameter of the above equations by a simple relationship, where *w* is the weight per unit area of the felt or sheet and *T* is the tension per unit width (9).

$$T = w\,y$$

By combining the previous two equations, an equation results which contains no coordinates.

$$T = w\,d + w(l^2/8d) \approx T = w(l^2/8d)$$

This shows that the tension of the paper is indirectly proportional to the length of the dip of the parabola. Tension is proportional to the length of the span but this will be a constant for a given papermachine. It is also proportional to the unit mass of the sheet, but it is highly impractical to increase tension by running higher basis weights or by having more moisture in the sheet at that point. The tension of the paper can therefore be monitored by keeping track of the dip. This length could also be controlled by changing the speed differential between the wet and dry ends of the papermachine.

EXPERIMENTAL METHODS

This experiment will be carried out on the papermachine at Converters Paperboard Company in Rockford, Michigan. This facility consists of a single papermachine with an open draw between the first and second presses. The experiment will consist of two different phases. The first of these is to install the position sensor over the draw and to monitor wet end break frequency, steam economy, and the optimum draw position, or tension, regarding these items. The second part of the experiment will be to link the position sensor to a control system which runs the main drive of the wet end. This control system will maintain the optimized draw tension at all times. The same parameters will still be monitored at this time to study the expected improvements in break frequency and steam consumption efficiency. Because the equipment will be installed by the mill employees, the technical details of the installation will not be included here.

The first step of this experiment will be completed by the mill. A laser device with the capability of sensing the relative position of an object in front of it to one-hundredth of an inch will be installed above the center of the draw between the first and second press of the machine. The signal from the laser will be directed to a twenty-four hour strip chart recorder which will monitor the position of the sheet in the draw for fluctuations and wet end breaks. It will also chart the voltage signal to the second press drive. A recorder already exists that can be used to calculate average steam consumption. The installation of the equipment will take about two weeks and the data collection process for this phase will continue for about two months. The goals to be met by the end of this phase are to know the wet end break frequency, the steam economy, and the optimum height of the draw according to the position sensor.

The second phase of this experiment will begin with the installation of a computerized control system to link the signal from the laser sensor to the main drive of the papermachine. The control system will be wired into the control room where the operator will be able to shut the system down as necessary. This control system will be programmed to maintain the draw position at a fixed height which is not to vary more than ±0.05 inches. The installation and setup time for this system is expected to take one month. After this another period of data collection will take place in which the same variables will be studied as were analyzed in phase one. This should last for another two months.

Data collection will take place two days per week for five hours. Break frequency can be studied for all operating hours of the two month period because the necessary information for this will be recorded on the strip charts. The entire experiment is expected to last roughly six months. An exact starting date is not known.

At the end of the data collection period, the difference in break frequency will be calculated as will the change in steam consumption of the dryer section. The final stage of the experiment will be to determine the cost effectiveness of this system through the analysis of the data collected during the experiment.

FUNDING

The funding for this project will be provided entirely by the Recycled Paper Technology Association. The necessary funds have already been made available and will be distributed to Converters Paperboard Company in Rockford, Michigan, as necessary.

FACILITIES AND EQUIPMENT

This experiment will be conducted at Converters Paperboard Company in Rockford, Michigan. The machine at this facility includes an open draw between the first and second presses which can easily be used for this experiment. Special equipment needed for this experiment includes a laser position sensor, a twenty-four hour dual signal capacity strip chart recorder, and a computerized control system to link the sensor and the main drive.

BUDGET

The following budget lists all of the costs involved with this experiment.

ITEM	HOURS	COST
EQUIPMENT		
Laser position sensor		$4200.00
Strip chart recorder		$1200.00
Allen-Bradley computer controller		$18000.00
EQUIPMENT INSTALLATION		
Laser position sensor		$500.00
Strip chart recorder		$200.00
Allen-Bradley computer controller		$7000.00
TRAVEL		
Mileage to and from Rockford	68@$19.20	$1305.60
PERSONNEL		
Hourly payments	160@$10.00	$1600.00
GRAND TOTAL		**$34005.60**

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