Sensorless Tension Control in Paper Machines

M. Aníbal Valenzuela, *Senior Member, IEEE*, John Martin Bentley, *Life Fellow, IEEE*, and Robert D. Lorenz, *Fellow, IEEE*

Abstract**—Proper operation of the dry end of a paper machine requires some type of sheet tension control. Present systems use either indirect-speed-control-based schemes, or sensor-based direct tension control utilizing load cells or swing rolls. The indirect schemes are inadequate for most newer machines, and both types of the commonly used sensor-based schemes are invasive, expensive, require either special, or extra rolls, and add complexity to the sheet runs.**

This paper proposes and evaluates sheet tension estimation using only conventional motor and control signals, present in all newer drive controllers, integrated into a process model observer. This observer-based approach eliminates the need for the invasive tension transducers, and may also be used to replace the inaccurate indirect speed control schemes.

Index Terms**—Paper machines (PMs), sensorless tension control, tension control, web machine tension control.**

I. Introduction

A. Sheet Tension Fundamentals

As THE SHEET is formed and leaves the presses at perhaps 30%–40% water, the sheet has essentially zero modulus of elasticity, and as an inelastic medium, cannot support any stress-producing tension (the reason for closed draws at wet-end sections). As the sheet progresses though the dryer sections, the sheet modulus of elasticity dramatically increases, section-to-section, to higher values as it reaches the final water content of perhaps 5% (air dry) at the paper machine (PM) reel. Air-dry modulus of elasticity values range from perhaps 400 000 lbf/in^2 for newsprint, to over 1 000 000 lbf/in^2 for high-quality bond sheets. It can be readily seen that the water content is the predominant factor determining the sheet modulus of elasticity in the machine direction. Without going through the math involving the sheet caliper (thickness), the sheet modulus of elasticity determines the lineal sheet tension in pound force per lineal inch (pli) for a given *steady-state speed* difference, regardless of the physical sheet length of a given draw span. This relationship is given by the following generalized per-unit equation:

$$\Delta Tens = E_t \cdot \Delta V \tag{1}$$

$$E_t = E \cdot t \tag{2}$$

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TABLE I
Tension-Related Sheet Characteristics

Property	News	Fine	LWC	Liner
Basis Wt. (lb/3000 ft^2)	29.4	35.7	34.9	71.8
Caliper (in)	0.003	0.003	0.002	0.022
Modulus of Elasticity ($\times 10^3$ lbf/in^2)	350 / 560	380 / 1350	1240 / 1450	380 / 743
Tensile Strength (Ultimate 2-Sheet) (PLI)	9.8/10	27/29	10/21	57/135

where

$\Delta Tens$ change in tension (p.u.);

E sheet modulus of elasticity in the machine direction;

t sheet thickness (caliper);

ΔV speed difference between sections (draw) (p.u.).

Table I summarizes typical salient tension-related characteristics for the most common grades of sheet and board [1].

A guideline for the most probable operating tension for a given sheet grade may be developed from this table, combined with utilizing papermaking experience in setting up a machine direction tension profile through the machine dry-end sections. Experience has shown that it is advisable to limit the section-to-section tension to perhaps no more than 10% of the tensile strength (ultimate breaking tension). This wide margin is needed to accommodate imperfect paper making conditions, such as "across the sheet" variations in moisture, caliper, etc., producing nonlinear sheet tension "across the sheet."

B. Tension Control Strategies

1) Speed Difference Indirect Tension Control: Since, for most paper grades, the slope of the stress–strain curve (the modulus of elasticity) is quite linear in the practical operating range as the stress increases up toward the fracture point, we get very predictable tension changes for a given speed difference between sections, *if the moisture content remains constant.* What is the significance of all this? Common sense prevails, and if the sheet moisture remains nearly constant at a given draw in the dry-end of the PM, a good precise speed controller should provide an excellent indirect method of tension control! We might conclude that a quality speed controller solves most of the problems in determining tension, since it inherently provides inertia compensation during dynamic speed changes as well as friction loss compensation, under all conditions in all elements of the drive train and load, since it theoretically is controlling the peripheral speed of the tension producing draw rolls.

Why does not speed control always do the job? Several factors deteriorate the performance of the speed controller as an indirect tension controller.

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Ian Pickup

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Electrical Drive Simulation with MATLAB/Simulink Viktor Perelmuter,2024-04-26 The chapters of this book discuss the modeling of electric drives taking into account their relationship with the technological process they serve which significantly affects the composition layout and characteristics of the electric drive There are no published books of this kind and this book fills a gap in the literature This book deals with electric drives for rolling mills paper machines a number of several hoisting and transport devices these installations are very common and very complex so that modeling methods in their development and study are mandatory The book focuses on issues such as the transmission of torque by elastic shafts the transmission of torque by an endless elastic belt in paper machines and conveyors the transmission of torque by friction of pressed rolls in the paper industry the consideration of the elastic properties of long ropes in some hoisting and transport machines and the effect of swinging a moving load in such machines More than 100 models of the electrical drives that are made with the use of the program environment MATLAB Simulink are appended to this book The aims of these models are to aid students studying electrical drives of the various manufacturing machines to facilitate the understanding of various electrical drive functions and to create a platform for the development of systems by readers in their fields This book can be used by engineers and investigators as well as undergraduate and graduate students to develop new electrical drives and investigate the existing ones *Algorithms and Computational Techniques Applied to Industry* Jorge Luis García Alcaraz,Arturo Realyvásquez Vargas,2022-06-21 This book presents algorithms and computational applications integrated in software that are being applied in the industry It shows how companies using these tools are more competitive and efficient in the use and resources management The book is organized in three sections depending on the supply chain stage procurement including contact with costumers and product design Production process including relationship with suppliers and among departments and Distribution including logistics and transportation Proceedings of the International Conference on Soft Computing Systems L. Padma Suresh,Bijaya Ketan Panigrahi,2015-12-07 The book is a collection of high quality peer reviewed research papers presented in International Conference on Soft Computing Systems ICSCS 2015 held at Noorul Islam Centre for Higher Education Chennai India These research papers provide the latest developments in the emerging areas of Soft Computing in Engineering and Technology The book is organized in two volumes and discusses a wide variety of industrial engineering and scientific applications of the emerging techniques It presents invited papers from the inventors originators of new applications and advanced technologies Issues in Electronics Research and Application: 2013 Edition ,2013-05-01 Issues in Electronics Research and Application 2013 Edition is a ScholarlyEditions book that delivers timely authoritative and comprehensive information about Radar and Sonar Research The editors have built Issues in Electronics Research and Application 2013 Edition on the vast information databases of ScholarlyNews You can expect the information about Radar and Sonar Research in this book to be deeper than what you can access anywhere else as well as

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