ABSTRACTS OF THE FOURTEENTH INTERNATIONAL CONFERENCE ON WEB HANDLING

June 5-7, 2017

Web Handling Research Center
Oklahoma State University
Stillwater, Oklahoma

TABLE OF CONTENTS

A Study of Oscillation 2
David Roisum, Finishing Technologies, Inc.

Machine Direction Registration Dynamics 2
Brian S. Rice, Rochester Institute of Technology
Robert L. Walton, Optimation Technologies

Optimizing Idler Diameter 2
Ronald J. Lynch, RJLynch & Associates, LLC

The Effect of Mass Transfer on Multi-Span Lateral Dynamics of Nonuniform Webs 2
Jerry L. Brown, Essex Systems

The Effect of Mass Transfer on Multi-Span Lateral Dynamics of a Uniform Web ... 2
Jerry L. Brown, Essex Systems

A New Model for the Steady State Deformation and Friction of Webs on Rollers 2
Dilwyn P. Jones, Emral Ltd.

Optimizing Nip Roller Systems 2
Timothy J. Walker, TJWalker and Associates Inc.

Nip Impinged Center-Winding Including a Nonlinear Beam Model 2
Cagri Mollamahmutoglu, Yildiz Technical University

Explicit Simulation of Wrinkle Formation Due to Web Non-Uniformity 2
Boshen Fu, Eric Gilgenbach, Katie Nackers and Russ Brumm, Kimberly-Clark Corporation

Using a Winding Model to Reduce Winding Defects 2
Amy Thuer, Avery Dennison

Data Analytics to Predict and Prevent Issues in Roll-to-Roll Manufacturing 2
Aravind Seshadri & Carlo Branca, Roll-2-Roll Technologies LLC

Calculation of Film Tension from Film Position and Roller Position 2
Günter Oedl, Brückner Maschinenbau GmbH & Co. KG

Boundary Conditions for Lateral Deformation of Webs Transiting Rollers in Roll-to-Roll Process Machines ... 2
J. K. Good, Yao Ren & Jinxin Shi, Oklahoma State University

The Nip Mechanics of Nano-Impression Lithography in Roll-to-Roll Process Machines ... 2
Yao Ren & J. K. Good, Oklahoma State University

The Winding Mechanics of Laminate Webs ... 2
Sheng Pan & J. K. Good, Oklahoma State University

Impact of Large Deformations of Webs Transiting Rollers ... 2
Jinxin Shi & J. K. Good, Oklahoma State University

Preventing Negative Issues at Nip Roller ... 2
Tom Bass, Mitsubishi Rayon Carbon Fiber & Composites, Inc.

Modeling and Computer Simulation of Zero Speed Splice Unwinds ... 2
Prabhakar R. Pagilla, Texas A&M University

Wrinkling Mechanisms of Non-Wovens with Spatially Varying Material Properties ... 2
Rich Hamm, Jeremy Carrle & Steve Lange, Procter & Gamble

Roller Nip Deflections ... 2
Kevin Cole, Optimation Technology Incorporated

Longitudinal Tension in a Web Span ... 2
Karl Reid, Moad Abudia & Ben Reish, Oklahoma State University

Lateral Behavior of Moving Webs: A New Look at Modeling and Control ... 2
Edison O. Cobos Torres & Prabhakar R. Pagilla, Texas A&M University

Measurement and Quantification of Baggy Webs ... 2
Ronald P. Swanson, 3M Company

Web Curl and Web Curl Measurement ... 2
Ronald P. Swanson, 3M Company

A STUDY OF OSCILLATION

By

David Roisum
Finishing Technologies, Inc.
USA

ABSTRACT

There are many reasons to consider oscillation. Most fall under the overall desire to smear out streakiness in web caliper (basis weight, gage, thickness, etc.) so that it doesn't build up on some downstream process; most particularly winders. Bagginess and corrugations are just a few of the many 'winding' defects that may be helped by oscillation. However, many defects are too wide to be economically remedied by oscillation. This is because most oscillating systems will require an additional trim loss. This forces an economic tradeoff between defect waste (and/or customer complaint) by not going *far* enough and trim waste by going *too* far. Exceptions are blown film because it oscillates the entire width (circumference of the bubble). Yet here we run into another limitation of oscillation that blown film suffers more than most. That it may not be oscillated nearly *fast* enough to avoid caliper buildup damage. This paper reviews the motivations in detail as well as the common machinery of oscillation. The paper also reviews the literature on the subject, that is in a word, nearly nonexistent. Next, a simple model is presented that can help guide the process designer in selection of oscillation stroke, speed and shape. Finally, the model results are compared to the nearly nonexistent application guidelines.

MACHINE DIRECTION REGISTRATION DYNAMICS MODEL OF A ROTARY PRINTING PRESS

By

Brian S. Rice[1] and Robert L. Walton[2]
[1]Rochester Institute of Technology
[2]Optimation Technologies
USA

ABSTRACT

We derive an analytical model of the machine direction registration dynamics of a continuous-web, electronic line shaft rotary printing press. We use the model to quantify the affect of tension disturbances on machine direction registration dynamics with different control schemes. With standard registration control schemes, we show the benefits of using a compensator roller vs. differential gear. Next, we develop a novel cascaded reference control scheme for a differential gear-controlled printing press that allows it to rival the performance of a compensator roller-controlled printing press. Finally, we demonstrate the benefits of using a cascaded reference empirically on a 6-station rotogravure printing press with differential gear control.

OPTIMIZING IDLER DIAMETER

By

Ronald J. Lynch
RJLynch & Associates, LLC
USA

ABSTRACT

The idler is probably the most common roller in web handling, but it is one of the least studied. It influences both the highest and lowest tension we can run, and can defeat the most sophisticated tension control schemes. Inertia and bearing drag both upset tension during transient conditions. Idler diameter is one variable that can affect both. Too small a diameter can result in wrinkles caused by deflection or web damage from bending stress. Too large an idler can result in loss of traction from air entrainment and unnecessarily high equipment cost. Hopefully, there is a diameter that can satisfy all requirements. This paper looks at several factors that must be considered while selecting the best diameter for idlers to minimize their impact on the web path.

THE EFFECT OF MASS TRANSFER ON MULTI-SPAN LATERAL DYNAMICS OF NONUNIFORM WEBS

By

Jerry L. Brown
Essex Systems
USA

ABSTRACT

In this paper, the concepts of mass transfer and boundary defect, introduced in a companion paper[1], are extended to models of non-uniform webs, including for example, cambered webs.

Included in this paper is a review of Richard Benson's, 2002 paper, "Lateral Dynamics of a Moving Web with Geometrical Imperfections". In it, he made considerable progress in the analysis of nonuniform web behavior. He,

Developed an acceleration equation that correctly incorporated shear, without realizing the connection to mass transfer, by equating the rate of change of face angle of the web at a downstream roller with the rate of change of roller angle.

Developed closed-form solutions for webs with,

A discontinuity in slope (splice)

Sinusoidal warping

Camber (laterally curved)

Some of the results of Benson's paper will be discussed, improved a bit and recast in a form that makes it easier to compare with other work.

THE EFFECT OF MASS TRANSFER ON MULTI-SPAN LATERAL DYNAMICS OF A UNIFORM WEB

By

Jerry L. Brown
Essex Systems
USA

ABSTRACT

This paper will show that the acceleration equation used in multi-span lateral dynamic models is a consequence of mass transfer between adjacent spans. Mass transfer fully accounts for the equation currently used in Euler-Bernoulli models and provides an analytical pathway to an acceleration equation that incorporates shear deformation. It also ties together contributions from three other researchers – John Shelton, who pioneered the use of beam theory in models of lateral web dynamics, Lisa Sievers, who proposed the principle of continuity of face angle and Richard Benson, who derived an acceleration equation that correctly incorporates shear deformation.

The acceleration equation is applied in conjunction with the normal entry rule to convert information about web shape to a time-based differential equation. Several versions of the acceleration equation have been proposed that include one or more terms to account for shear. All but Benson's lead to results that either contradict observed web behavior or else fail to provide meaningful solutions.

Consideration of mass conservation arises from the moment of force that develops in a web when it is displaced by an upstream disturbance or by movement of a roller that is transporting it. Any moment at the entry to a roller causes the longitudinal tension to vary in a linear fashion across the width of the web. Analysis of the consequences of this tension profile leads to: 1) The acceleration equation that is currently used for models without shear deformation. 2) A new understanding of why this equation works and improved insight into how multi-span systems behave 3) An acceleration equation for models that include shear deformation 4) Identification of a new mechanism that can cause micro-slip at the point of entry onto a roller.

A NEW MODEL FOR THE STEADY STATE DEFORMATION AND FRICTION OF WEBS ON ROLLERS

By

Dilwyn P. Jones
Emral Ltd.
UK

ABSTRACT

A web moving through process machinery interacts with rollers through frictional forces, which may change its direction of motion and tension. By modelling the web as a beam, these forces can be calculated from its tension, curvature and angle, at all points in contact. In turn, the forces can be combined to give distributed forward and lateral forces and a distributed moment, which determine the beam deformation. This approach was introduced in an earlier paper [1], and applied quantitatively to the "stick zone", where web and roller surface velocities match. Now it has been extended to microslip zones in steady state, the transitions to stick zones, and free spans.

A numerical model calculates the microslip zone length, variation of lateral displacement, web angle, bending moment, shear, tension and motion relative to the roller surface. In the microslip zone just before the web leaves a roller into a free span, the behaviour is surprisingly complex, with an unexpected interaction between steering and web tension, and reversal of web angle during contact. The effects of misaligned or tapered rollers, tension change, incoming web shear and camber can be examined separately and in combination.

The model has also been applied to interacting spans, where misalignment in one span steers the web in the reverse direction in the preceding span (sometimes known as "moment transfer"). Microslip occurs over the whole wrap of the roller between the two. At onset, the exit microslip zone length on this roller is equal to the wrap length: the model predicts the misalignment when this occurs. Extension to the preceding span gives agreement with the experimental results and simpler model of Good [2].

The beam equations indicate that a microslip zone at roller entry followed by a stick zone is only possible if the web shear is sufficiently large. Otherwise, there is no microslip zone, and the web strain at end of the span matches that on the roller. If the

microslip zone exists, the bending moment and shear fall from their values at entry to those in the stick zone, where shear is supported by a static frictional moment.

The model provides a new, more complete picture of web behavior on rollers. It could find application in detailed analysis of steering guides, problems with cambered webs, and the occurrence of micro-scratches from steering - alone and in combination with tension changes.

Jones, D.P., “The Behavior of a Flexible Web in Contact with a Roller,” Proceedings of the Twelfth International Conference on Web Handling. Ed. Good, J. K., Oklahoma State University, 2013, to be published.

Good, J.K., “Shear in Multispan Web Systems,” Proceedings of the Fourth International Conference on Web Handling. Ed. Good, J. K., Oklahoma State University, 1997, pp. 264-286.

OPTIMIZING NIPPED ROLLER SYSTEMS

By

Timothy J. Walker
TJWalker and Associates Inc.
USA

ABSTRACT

Nipped rollers are central to many web converting processes – printing, coating, embossing, calendaring, and winding. Uniform products require uniform load and pressure from the nipping process. Uneven nipping not only creates product variations, but can lead to high levels of waste from shifting or wrinkling the web.

Imperfections are inherent in nipping – from variations in roller diameters, product thickness, and roller deflection. For most nipped process, many variations are hidden by the compliance of a rubber roller covering. However, any nipped roller system has competing design factors. Hard rubbers last longer, but are less compliant. Smaller diameters create higher pressure, but will have more deflection under uneven loading. Is there an answer or guideline to rubber roller mechanics besides "What did you use before?"

This paper reviews the process of balancing rubber covering and roller design. One simple goal: ensure roller bending deflections are less than rubber roller compliance. The models for rubber covering and roller deflection will be combined to give a clear view and provide design guidelines to ensure this goal is achieved. In addition, the paper will review methods to assess nipped process uniformity and remedies to create more uniform nipped processes.

NIP IMPINGED CENTER-WINDING INCLUDING A NONLINEAR BEAM MODEL

By

Cagri Mollamahmutoglu
Yildiz Technical University
TURKEY

ABSTRACT

Nip pressure is commonly applied in winding processes in order to maintain structural stability and prevent air entrainment at high speeds. In nip induced winding modeling nip and roll are assumed to be beams with representative springs for the stiffness of the roll material between them [1], [2]. Depending on the application, typical rolls can measure up to more than 5 meters. Thus corresponding nip rolls, depending on the end constraints, bends and/or rotates considerably in order to fit to the roll profile especially in case of rolls which are wound from webs with length-wise persistent thickness variations. These bending deformations and/or rotations which can attain larger values for slender nip beams requires geometrically nonlinear formulation for realistic modeling of the process. In this study an axis-symmetric winding model, a roll compaction model and a nonlinear beam model coupled in order to simulate center-winding with a nip. Winding model calculates inner stresses and strains and updates the geometry and material properties with respect to incoming CMD tension profile. In the same time, as winding simulation continues, compaction model produces representative materially nonlinear radial stiffness coefficients for the wound roll in radial direction. These nonlinear springs, differing in height (in radial direction) are engaged by the representative nip beam in order to calculate the associated nip induced pressures along CMD on the wound roll. Finally these values in turn are used for calculation of the incoming tensions at various CMD locations for the winding model. The complete model uses an axisymmetric winding model [3] and a roll compaction model [4] previously developed by the author. The integration of the nonlinear beam model for the nip beam representation is the original contribution of this study. Von Karman strains are assumed for the nip beam and a finite element formulation is developed and integrated into the general algorithm. Effects of persistent web thickness variations, level of nip pressure and nip beam's slenderness ratio are studied under various end conditions. Usage of a nonlinear formulation vs. a linear formulation are compared as well.

Hoffecker, P., "The Analysis of a Nip Impinged, Three Dimensional Wound Roll," PhD dissertation, Oklahoma State University, 2006.

Mollamahmutoglu, C., "A 2D Axis-symmetric Wound Roll Model Including Nip Effects," PhD dissertation, Oklahoma State University, 2009.

Mollamahmutoglu, C., and Good, J. K., "Modeling the Influence of Web Thickness and Length Imperfections Resulting from Manufacturing Processes on Wound Roll Stresses," CIRP Journal of Manufacturing Science and Technology, Vol. 8, 2015, pp. 22-33.

Mollamahmutoglu, C., Ganapathi, S., and Good, J. K., "Pressures on Webs in Wound Rolls due to Winding and Contact," Tappi Journal, Vol. 13, 2014, pp. 41-50.

EXPLICIT SIMULATION OF WRINKLE FORMATION DUE TO WEB NON-UNIFORMITY

By

Boshen Fu, Eric Gilgenbach, Katie Nackers & Russ Brumm
Kimberly-Clark Corporation
USA

ABSTRACT

It is very common to laminate different materials together and then form, transport and process a web with non-uniform structure in the product manufacturing industry. The periodic media analysis (PMA) method in Abaqus/Explicit [1] has been applied to simulate web wrinkle formation due to web non-uniformity during web transportation. This is a further application of previous PMA simulation models [2]. In this work, an experiment has been conducted to test a web structure including two materials with significant differences in terms of thickness and material properties running through rollers. Wrinkles have been observed during the experiment. Based upon the experimental setup, a web handling model is generated using the PMA method. This model can capture wrinkle formation due to web non-uniformity which agrees with experimental observation. The model and information provided by this model can be used to study wrinkle formation due to similar root causes and explore solutions to prevent wrinkles from occurring in future applications.

Abaqus Analysis User's Manual, Section 10.5, 2016.

Fu, B., and Michal, N., "Explicit Simulations of Web Transport through Process Machines Using Periodic Media Analysis Technique," Proceedings of the Twelfth International Conference on Web Handling. Web Handling Research Center, Stillwater, Oklahoma, June, 2015.

USING A WINDING MODEL TO REDUCE WINDING DEFECTS

By

Amy Thuer
Avery Dennison
USA

ABSTRACT

As a roll is wound, stresses in the roll develop – and change as the roll builds. The stresses on each layer in the wound roll influence whether the roll is likely to telescope, star, cinch, yield, block or ooze – to name just a handful of winding defects.

Finding the right balance between too tight and too loose defects can take significant trial time and material. Changing several winder inputs simultaneously increases the problem complexity – especially if a wide range of materials is also involved.

This paper discusses how a 1D winding model can be used to speed the troubleshooting process to optimize winder settings to avoid winding defects.

DATA ANALYTICS TO PREDICT AND PREVENT ISSUES IN ROLL-TO-ROLL MANUFACTURING

By

Aravind Seshadri and Carlo Branco
Roll-2-Roll Technologies LLC
USA

ABSTRACT

Data analytics or big data is used in a variety of industries such as retail, healthcare, education and entertainment to gain significant insights from the underlying information. These insights are used to attract, retain and grow customers by providing solutions that are tailored to specific customer needs.

Application of advanced data analytics to improve productivity in manufacturing applications is also gaining traction. Traditional techniques such as lean and six-sigma still dominate the manufacturing industry. However, advanced analytics is used in complex manufacturing applications where the number of variables that influence the overall productivity is large.

Roll-to-roll manufacturing, being a complex manufacturing process, can benefit from insights gained from data analytics to improve process efficiency and to reduce waste. This paper highlights the use of data analytics to predict and prevent web handling issues to improve process efficiency and to reduce waste. New sensing and measurement technologies to detect web flutter, wrinkles/creasing, necking, cambered webs, etc, are first presented. These sensor measurements are then used in a model to gain insights from the raw data. These insights are in turn used to predict and prevent web handling defects. A few application examples based on data from experiments will be presented to showcase the use of data analytics for fault prediction in roll-to-roll manufacturing applications.

CALCULATION OF FILM TENSION FROM FILM POSITION AND ROLLER POSITION

By

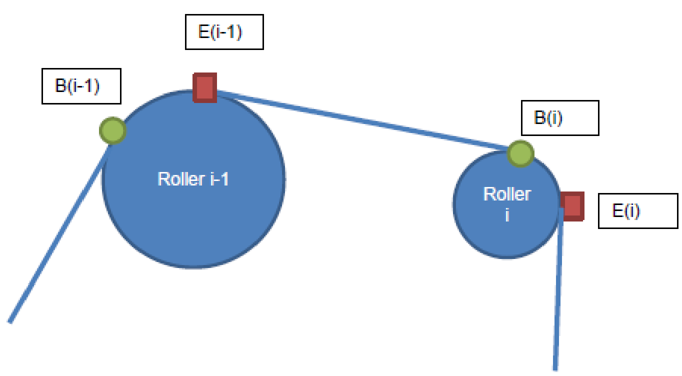
Günter Oedl
Brückner Maschinenbau GmbH & Co. KG
GERMANY

ABSTRACT

The basic Idea of this concept is, that in todays drive system the feedback is not a speed feedback, but a position feedback. So the Position of the roller is for free. In the film the actual stretching state (elastic elongation, thermal expansion or creeping etc.) affects the length of the film more directly than the speed. So we build up a model based on position of roller surface and the amount of film fed into the system.

The film consists of spans between two adjacent rollers (tangent to the two rollers starting in point E(i-1) and ending in B(i) and the part of the circle (circular arc or circular segment) on the roller (from B(i) to E(i)).

The length of those parts can be calculated from the position of the roller centers and the radii.



The film itself is transported by the rollers. The speed of the film between the rollers i-1 and I is the surface speed f roller i, that means the speed of the span is the surface speed of the next (downstream) roller. [Reference Brandenburg or other] The speed of film on the roller i is also the surface speed of the film on that roller.

Rem. This second assumption is not 100% true, because the film starts slipping at the end of roller coming to the point E(i). This is described in the file "micro slip". But for a first concept this assumption above is good enough.

So the film speed only can change at the points E (at the end of every roller).

The next assumption is, that the film is only stretched elastically (no plastic deformation, no viscoelasticity). *Rem.: This second assumption is not really needed, but makes the understanding easier.*

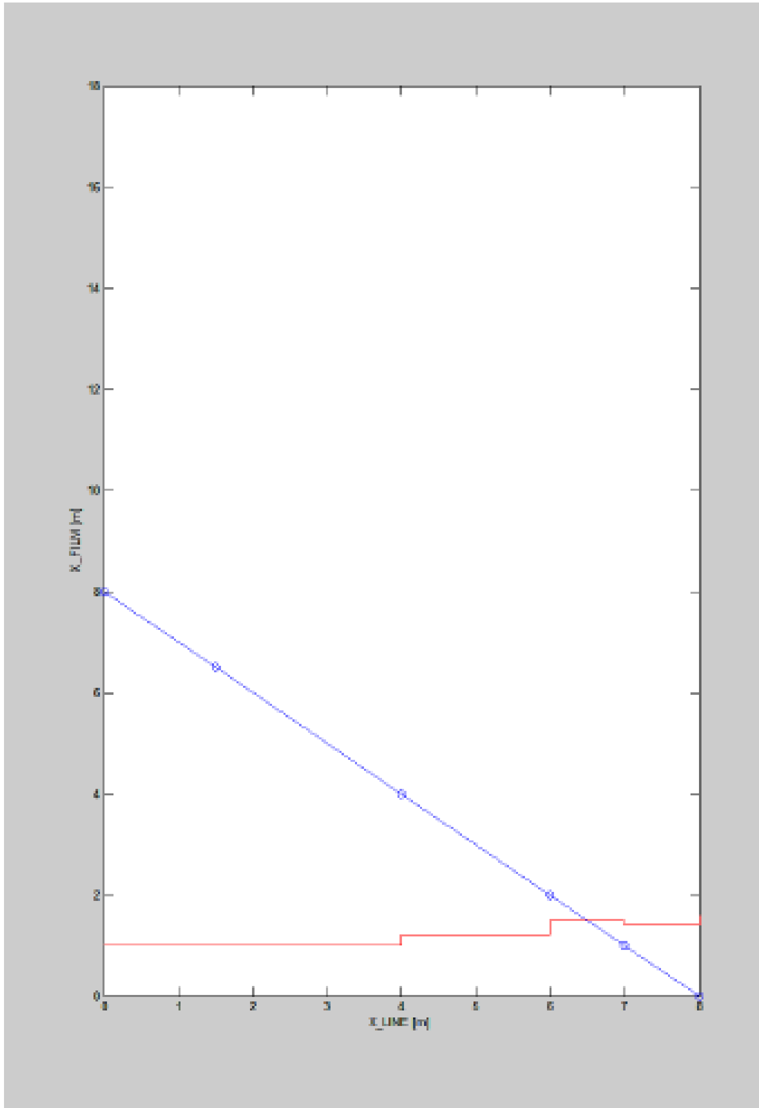
We also assume that the film had some marker on its surface showing every meter (or mm) of the film at the initial state of the film (like the Chill Roll had some engravings, which is transferred to the film). If the film is stretched, those marks separate, but always refer to their original distance.

We define two sets of length:

x_line is the length at the level of the film. It can be imagined as a measuring tape, which had been inserted in the line before startup. The only information we need to write down are the line positions of the points E(i).

The other length is **x_film**, this is the length of the film, running down the same length, but the units are the meters of original film. This is the idealized embossing on the film from the chill roll.

If we start the model of the line, we start with 0 m film at position 0 (l_line). After one meter has passed the 0 m of film has reached 1 m in x_line. At position 0 of line, the film with the length 1 m is passing. If we have a "small" machine (line) consisting of 6 rollers with the points E at 0; 1.5; 4; 6; 7 and 8 m we have following picture: The markers on the blue line show the positions E1 o E6.



The blue line shows the x_film over x_line. In the first step this is a -45 degree line: no stretching of film at all. To make the starting point easy to understand, we have deliberately chosen the point, when the film length (x_film = 0) has reached the end of our line (x_line = 8m).

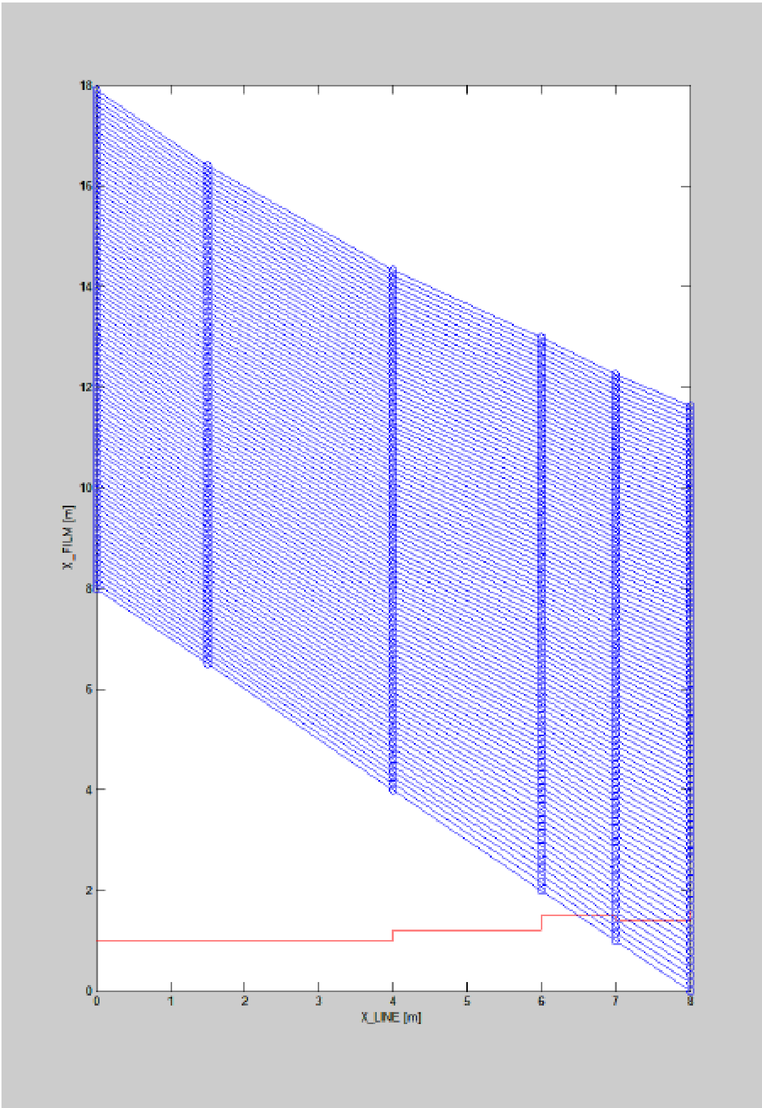
Rem.: Please note, that the direction of l_line goes left to right (downstream rollers will have a higher value) whereas the x_film goes right to left and showing film parts with a higher number being closer to the Chill Roll. As a result, the line goes down.

For this starting time of the model at the begin of the line, x_film = 8, just because the we start we no elongation. This will change later.

During running the line, we take for every time step the move of each roller.

Rem.: The time step should be so small, that the move is small compared to the film span length.

For every roller we calculate the move “mv_rol” for one time step, i.e. speed of roller times time step. Now we look for the film length (x_film), which will be at the points E at the end of this step. Is must be the point, which is exactly mv_rol upstream of the point E before that move. This can be done with a linear interpolation.

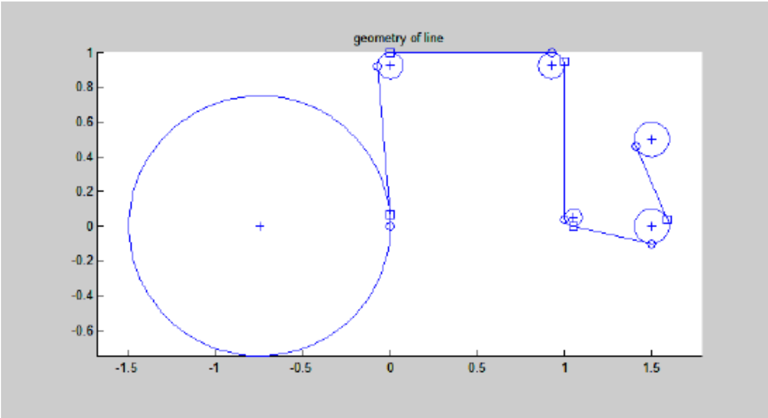


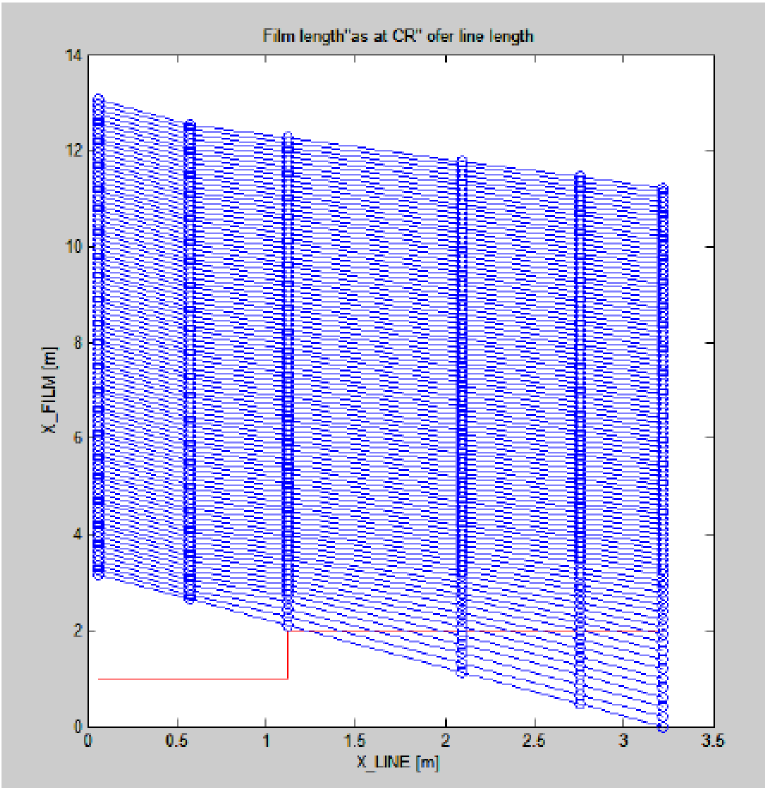
After a time of 10 seconds we see the situation in the in this chart: every blue line shows the situation a certain time stamp (here every 0.1 secs). Starting from the lowest line with no elongation, we see the film being stretched according to the roller speeds shown in red.

The good things of his type of calculation are:

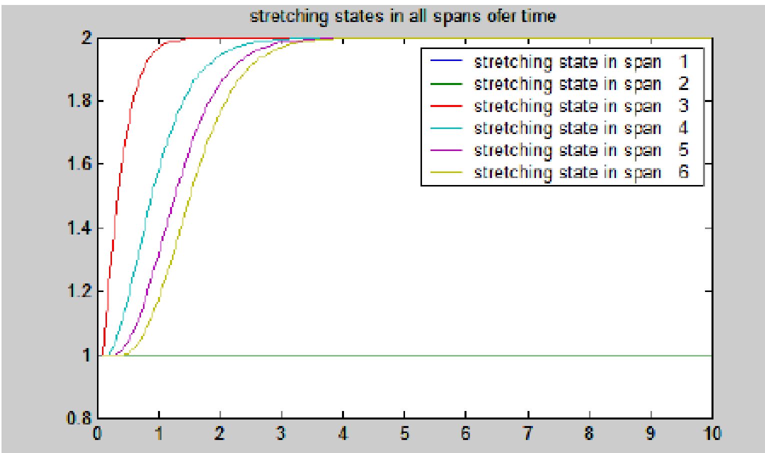
It is easy to calculate: only linear algebra (no exponential, like other models)
It only needs the roller position at the end of every step.
Speed peaks do not result in noise, as only position is used.
Film tracking (following a spot of film through the machine) comes as an automatic output. This can help identifying errors and tracking them from a part in the machine to the product.
The forces of the film can be calculated, as the elongation is known and the Young modulus should be known.
For films being heated up the elongation can be separated into thermal expansion and elastic elongation.

Second example





The stretching states before each roller (span):



It can be seen, that starting at state 1 (no elongation): each span gets the stretched film later.

This approach can be used for analysis of film motion and film forces in the first step. It also is helpful for tension control (tension is direct output of roller position). It also can be used for detection of slip-stick effect.

BOUNDARY CONDITIONS FOR LATERAL DEFORMATION OF WEBS TRANSITING ROLLERS IN ROLL-TO-ROLL PROCESS MACHINES

By

J. K. Good, Yao Ren and Jinxin Shi
Oklahoma State University
USA

ABSTRACT

The lateral deformations of webs in roll-to-roll (R2R) process machines can affect the quality of the manufacturing process. The lateral registration of the web in successive R2R processes can determine whether a product will function as designed. Herein a unified theory is presented that explains how imperfections in rollers, their alignment and length non-uniformity (camber) in webs can affect the steady state lateral deformation and hence registration. Enhanced understanding of steady state lateral deformation of webs transiting free spans and rollers will provide insight for advanced control methods that account for the effects of web deformation in minimizing registration error. The validated results show that the lateral deformations can be predicted with closed form expressions. In some cases the boundary conditions which are integrated into these expressions must be determined using dynamic simulation.

THE NIP MECHANICS OF NANO-IMPRESSION LITHOGRAPHY IN ROLL-TO-ROLL PROCESS MACHINES

By

Yao Ren & J. K. Good
Oklahoma State University
USA

ABSTRACT

Nano-Impression Lithography (NIL) has been demonstrated to produce nano features on webs that have value to society. Such demonstrations have largely been the result of NIL processes that involve the discrete stamping of a mold with nano-impressions into a thermoplastic web or a web coated with resin that is cured during the imprint process. To scale NIL to large area products which can be produced economically requires the imprinting to occur on roll-to-roll (R2R) process machines. Nip mechanics is a topic which has been explored in relation to drive nips and winding nips in R2R machines. Nip rollers will be needed to imprint webs at production speeds to ensure mold filling on an imprint roller. The objective of this paper is to demonstrate while the nip roller is required that it can also induce imperfections in the imprinted nano-features. Successful imprinting may require specialized nip materials and tension control of the web entering and exiting the nipped imprint roller.

THE WINDING MECHANICS OF LAMINATE WEBS

By

Sheng Pan & J. K. Good
Oklahoma State University
USA

ABSTRACT

Models that describe the residual stresses due to winding single layer webs at the end of roll-to-roll manufacturing machines began development over 50 years ago. These models have been used to reduce or avoid defects that are due to winding. Many laminated products exist where two or more webs have been joined to form a thicker composite web. The properties of each layer provide a unique functionality to the product. No laminate winding models exist in the literature. This paper will focus on the development of a laminate winding model and lab test verification of the model.

IMPACT OF LARGE DEFORMATIONS OF WEBS TRANSITING ROLLERS

By

Jinxin Shi & J. K. Good
Oklahoma State University
USA

ABSTRACT

Webs are subjected to large out-of-plane deformations when transiting rollers in process machinery. Webs are often treated as membranes in analysis but become subject to significant bending strains when transiting rollers. Anticlastic bending of thick plates is a known phenomenon. The anticlastic effect is often ignored for webs which are thin. The objective of this paper is to demonstrate that the large bending deformations webs are subjected to on rollers influence the internal membrane stresses in the web. It will be shown that a cross direction tensile membrane stress results that acts to stabilize the web and inhibit wrinkle formation.

PREVENTING NEGATIVE ISSUES AT NIP ROLLER

By

Tom Bass
Mitsubishi Rayon Carbon Fiber & Composites, Inc.
USA

ABSTRACT

Preventing issues at the nip roller can decrease waste and increase efficiencies and profitability. The issues can be caused by the historically bulky steel or aluminum roll designs. These type nip rolls can lead to higher roll deflection, lower critical speed, and less consistent contact area across the roll face. These issues can lead to slower processing speeds, higher contact force, and reduced efficiencies and profitability.

Advancements in the development of lighter weight carbon fiber composite rolls can address the issues facing wide web printers, coaters, laminators, film producers, etc. Through specialized roller engineering, carbon composites rollers can be designed to reduce roller deflection, maintain consistent contact across the face of the roller under various load conditions, and include a lightweight roller body that reduces bearing strain, increases critical speed, and can lead tom improvements in efficiencies and profitability.

This presentation reviews the advancements in carbon fiber composites rollers in the converting industry and how specific applications can be improved with a highly engineered double-pipe roller that is designed to improve function at the nip roller. These carbon composites rollers can be utilized in situations with limitations on roller OD by being able to utilize a low OD and wide web width without compromising roller deflection levels as seen with steel or aluminum rollers.

MODELING AND COMPUTER SIMULATION OF ZERO SPEED SPLICE UNWINDS

By

Prabhakar R. Pagilla
Texas A&M University
USA

ABSTRACT

Web lines to manufacture personal care products often use zero speed splice unwinds with festoons to facilitate roll change. These unwinds are a leading source of waste and delay, and for most part are set up using trial and error. Scientific knowledge and systematic procedures that would help in the selection of configuration and operational parameters for the unwind process are limited. This is a significant problem given that there are thousands of zero speed splice unwinds in existence in the industry today. Recent emphasis by companies to use lighter basis weight webs in order to reduce cost and employ higher speeds to expand into global markets has exacerbated this problem even more; lighter webs are more prone to wrinkles, neck-down and web breaks. Therefore, there is a significant need to develop systematic scientific procedures based on mathematical models and computer simulation of those models to efficiently setup the unwind system and run the unwind process.

Three aspects associated with the unwinds are essential in developing systematic guidelines for the unwind operation during zero speed splicing: (1) a suitable model that reflects the web transport behavior as well as the dynamics associated with the mechanical components; (2) analysis of the model to optimize speed profiles and select reference values for transport variables that would lead to improved transport behavior in the unwind; and (3) model simulation to evaluate system behavior for a variety of possible operating conditions and experimental validation. These three aspects will be described in this paper.

The unwind model is developed by considering existing literature on the topic and some key observations on production unwinds. A typical unwind roll change strategy is employed for the development of the model and its validation: (1) over speed of the expiring unwind roll to fill festoon; (2) deceleration of the expiring roll to zero-speed; (3) web cut from the expiring roll and splicing of the web from the new roll to the web in the festoon; and (4) acceleration of the new roll to the desired line speed. Although this

sequence of events is quite standard from an unwind operation viewpoint, one has to systematically consider the selection of speed profiles and the time associated for each event while considering the physical constraints of the unwind, such as festoon capacity, clamp and dwell time, etc. The model consists of governing equations for web speed on each roller and tension in each span, which can be conveniently used to set up a computer model simulation. The paper will describe such a computer model developed in MATLAB/SIMULINK. In addition to the computer model, the paper will also describe a systematic procedure for determining splicing parameters, such as acceleration and deceleration rates, start diameter, etc. The computer model can be used to evaluate different scenarios of unwind operation prior to actual implementation on production unwinds. Thus, providing a significant benefit in terms of operational efficiency as well as improved process capability.

WRINKLING MECHANISMS OF NON-WOVENS WITH SPATIALLY VARYING MATERIAL PROPERTIES

By

Rich Hamm, Jeremy Carrle & Steve Lange
Procter & Gamble
USA

ABSTRACT

Webs often include variation in caliper or modulus of elasticity as a result of manufacturing variation. Light-weight webs are especially prone to these issues because the variation is proportionally more when compared to the average modulus. It is proposed that the length scale variability in fiber orientation and most importantly mass density extends to the mechanical properties of the web including degree of orthotropy and Poisson's ratio (neck-down) behavior. Finite element simulations show that materials exhibiting this kind of variability (in MD and CD modulus, and Poisson's ratio), notably with nominally 'high' and 'low' regions alternating in the MD, leads to trough and wrinkle formation. Multiple simulations with varied material properties have led to a greater understanding of the mechanisms and conditions that cause these types of wrinkles.

ROLLER NIP DEFLECTIONS

By

Kevin Cole
Optimation Technology
USA

ABSTRACT

Rubber covered nip rollers are used in many web handling and processing applications. Successful use of these systems requires an accurate knowledge of the impact of various design and process parameters on such key response metrics such as nip pressure and surface speed axial uniformity. These metrics are important since they are directly correlated to operational and functional requirements of the nipping process. Axial variations occur primarily due to roller shell bending, which arises from externally applied end loading forces. The non-linear radial compressive characteristics of elastomeric coverings that are often a part of such systems further contributes to system complexity. Previous papers have presented a two-dimensional analytical model that relates force and deformations of rubber rollers in contact with other rollers. In this paper, a three-dimensional model is presented that extends the previous model by incorporating bending deflections. In addition to the non-linearity due to the compressive characteristics of rubber coverings, the model also includes the ability to include other non-linearity's such as roller diameter non-uniformities and misalignment, or skew, of the roller's rotation axes. The model is used to demonstrate that the use of crowning or skewing must not only account for geometric effects but also the nearly incompressible nature of rubber coverings to successfully mitigate axial nip pressure variation that otherwise is present in end-loaded nip roller systems.

LONGITUDINAL TENSION IN A WEB SPAN

By

Karl Reid, Moad Abudia & Ben Reish
Oklahoma State University
USA

ABSTRACT

Longitudinal tension in a web span depends on several factors including the incoming web speed, the outgoing web speed, the current value of the web tension, the previous span tension, and the span length. In an effort to emphasize the importance of first principles modeling of a web line using primitive elements, this paper focuses on the variable span length effects on the longitudinal tension using a nonlinear span model. A varying span length may occur as a result of non-circular unwind and idle rollers, as well as eccentric rollers. The entry section of a typical roll-to-roll web line will be modeled using both linear and nonlinear span models. Comparisons will be made of predicted and measured tension results to illustrate when the nonlinear model should be used. It will be demonstrated that the nonlinear model is useful in studying disturbance rejection in a web line with and without a dancer following the unwind roll.

LATERAL BEHAVIOR OF MOVING WEBS: A NEW LOOK AT MODELING AND CONTROL

By

Edison O. Cobos Torres & Prabhakar R. Pagilla
Texas A&M University
USA

ABSTRACT

There have been many studies on modeling the lateral behavior of moving webs, dating back to about 60 years. The first seminal work on the topic was reported by Shelton in his Ph.D. thesis in 1968. For the purpose of deriving the governing equation for the web lateral position on rollers, Shelton treated the moving web between two rollers as a tensioned Euler-Bernoulli beam. He correctly argued that, for most webs, the web mass is negligible, i.e., the force due to acceleration of web mass is negligible when compared to web tension, and, thus, treating the lateral motion of the web between two rollers as the motion of a static beam. He considered four boundary conditions (web lateral position and slope on each roller) to solve the differential equation describing the motion of the static beam. Shelton also used a key observation/principle that was prevalent in the transport of belts literature that a belt approaching a roller aligns itself normal to the axis of rotation of the roller; he used this principle to setup two normal entry conditions, one for lateral velocity and the other for lateral acceleration in terms of roller web velocity, web entry angle at the roller, lateral position and angle of the roller. Based on this approach, he derived transfer functions from the guide roller lateral position (input variable) to web lateral position on the roller (controlled or output variable) for various guide roller mechanisms, such as the end-pivoted guide, center-pivoted guide, offset pivot guide, remotely pivoted guide, etc. Subsequent work specific to modeling and control of web lateral dynamics based on this treatment was reported by Sievers (1987), Young and Reid (1993), Seshadri and Pagilla (2010), and Brown (2013).

In this paper, we further investigate and discuss some of the inherent assumptions of the aforementioned approach that have implications for modeling and control of web lateral behavior. First, the solution for the beam equation was obtained by assuming constant (time- invariant) boundary conditions, and subsequently the time derivative of the solution is used in the normal entry conditions to determine the transfer function. We argue that the purpose of the guide roller is to modify the boundary conditions, and therefore the time-invariant assumption on the boundary conditions is counter to the

notion that the axis of rotation of the guide roller is utilized to change the web boundary conditions on the roller. Second, the existing approach provides a governing equation only for the lateral position behavior on the roller and not for any position within the span. Third, existing methods focus on controlling just the lateral position and not the web slope; we argue that one needs to control both the lateral position and slope, so that lateral oscillations are not propagated downstream of the guide roller. We will discuss these three aspects and present some new ideas and developments in lateral modeling and control which address some of the aforementioned issues. In particular, we will discuss development of governing equations (transfer functions) for different guide mechanisms that provide web lateral position at any point spatially along the length of the span and discuss strategies to control the lateral behavior in an effort to minimize propagation of lateral oscillations.

MEASUREMENT AND QUANTIFICATION OF BAGGY WEBS

By

Ronald P. Swanson
3M Company
USA

ABSTRACT

Webs that have crossweb variation in machine direction length are commonly called "Baggy Webs". All real webs have some degree of bagginess. When the bagginess exceeds some quantity, web handling problems such as wrinkling and lateral motion begin to appear.

There have been many articles, technical papers and patents on the subject of web bag measurement. This paper will summarize the measurement methods in the open literature. Mathematical techniques will be presented to analyze these measurements. A new concept of "Web Bag Strain" will be presented for the quantification of baggy webs.

WEB CURL AND WEB CURL MEASUREMENT

By

Ronald P. Swanson
3M Company
USA

ABSTRACT

Products manufactured in Roll-To-Roll processes can exhibit curl defects caused by these processes. This paper will review the literature on the subject, some of the common causes of curl and common solutions will be presented. This paper will also discuss current measurement test methods and present a new and improved measurement method.