ABSTRACT

The secondary arms on a conventional pope reel control the nip load between the winding parent roll and the reel drum. As the parent roll grows, the secondary arms pivot away from the reel drum changing the angle of contact on the spool bearing housing. This changes the magnitude of the component of force that contributes to nip load. The moment caused by the secondary arm center of mass also changes as the roll grows. These two effects combine with actuator geometry to create a sinusoidal relationship between cylinder pressure and nip load.

Older reels typically relied on constant pressure control to maintain the nip load. Operators could manually adjust the pressure as they thought was required. Once programmable logic controllers (PLCs) became popular, the changing geometry of the secondary arms could be compensated for making constant nip load practical. A look up table or polynomial in the PLC was used to create the pressure versus diameter function required for a constant nip load.

The effect of these two control methods on internal roll stresses has not been publicly documented to this author’s knowledge. The purpose of this work was to compare the internal roll stresses created by these two methods to gain insight into the benefit of constant nip load control. The question of whether the differences cause or solve any winding defects was beyond the limited scope of this study.
ABSTRACT

Where does the entry angle come from? This seemingly simple question goes to the heart of lateral web dynamics. In a beam model of lateral web behavior, entry angle refers to the angle between the tangent to the web centerline and the normal to the roller axis at the line of entry onto the roller. Whenever the entry angle becomes non-zero, the web, moving longitudinally through a process, will move laterally on the roller in a direction that returns it to zero. This behavior seems intuitively obvious if the web is modeled as a perfectly flexible string because it bends sharply at both ends when a roller is pivoted or moves laterally. However, in the case of the most commonly used Euler-Bernoulli (E-B) beam model the web can't make a sharp bend. If it is initially perpendicular to the roller axis, it should remain perpendicular as the roller is shifted or pivoted, assuming as we always do, that there is no slipping. We know from experience, however, that a real moving web begins to move laterally soon after a roller pivots or shifts? The first explanation that comes to mind is shear deformation, which is not accounted for in the E-B model, but it is too small to explain the observed velocities. So, where does the entry angle come from? This paper will show that the answer to this question reveals a connection between longitudinal and lateral behavior that has, gone largely unnoticed.
ABSTRACT

Once it is known that lateral behavior depends on the redistribution of mass between spans [1, 2] it is natural to consider the possibility of a model that combines lateral and longitudinal (tension) behavior. This paper will describe such a model. Nonlinear elasticity theory is used to model the web as a two-dimensional membrane in a state of plane stress. Boundary conditions at the downstream roller are 1) the normal entry equation, used in lateral models, and 2) the continuity equation, used in tension models. Many of the results from the new model, such as CD averages of lateral force, lateral position face angle and slope are shown to agree closely with values from beam models developed and tested by Shelton [3] for his 1968 dissertation.

Implications of the following types of information, unavailable from one-dimensional beam models, are presented and discussed.

1. CD Gradients in lateral velocity created by tension profiles at the downstream roller.
2. Longitudinal tension disturbances created by pivoting and shifting of rollers

REFERENCES

ABSTRACT

For those concerned with roll quality it is difficult to suppress the urge to compress the outer surface of a wound roll with your thumb to sense how the roll was wound and how large the internal pressures might be. If several rolls of a given web are wound at unique tensions a human could often arrange these rolls in order of ascending winding tension using their thumb test. What is sensed is the relative conforming deformation of the roll surface compared to that of our thumb. A soft roll would deform more and have greater contact area with our thumb than a hard roll for a given load. The thumb test described would be most useful on softer rolls wound from nonwovens, tissues, some grades of paper and polymer films but less so on metal coils that deform little in comparison to our thumb. The physics define stiffness as the extent to which an object resists deformation in response to an applied force. This publication reports the results of research where the stiffness of the outer surface of a wound roll is used to characterize the internal residual stresses due to winding throughout the roll. Measurements of stiffness of the outer surface of wound rolls will be demonstrated using commercial and handheld devices that have greater resolution than the thumb. These measurements will be coupled with models to allow the exploration of internal residual stresses in the wound roll that can be used to investigate winding defects and roll quality.

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ABSTRACT

The storage time of webs in the form of wound rolls can be quite long. The strain in a web has two components. The web has a membrane strain level due to web tension in the winder tension zone. Those membrane strains are modified as a result of the winding mechanics. The wound roll builds in outer radius during the winding process; a specific web layer will enter the wound roll at a unique radius. This introduces a second component of strain in the form of a bending strain. Depending on the web thickness and the radius a layer is wound into the roll, these bending strains can be much larger than the membrane components. Many webs are viscoelastic on some time scale and will creep through time while stored in roll form. At some point in time the web will be unwound and cut to the size requirements of a discrete product. With no tension on the discrete web it may be unable to lie flat. This is considered a defect which is called curl, the combined result of strain variation through the web thickness and creep. The objective of this publication is to provide a method by which process engineers can explore and mitigate curl defects in webs.

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THE LATERAL DYNAMICS OF CAMBERED BELTS

By

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ABSTRACT

Previous experimental and analytical studies of web camber on the lateral steering of webs have focused on the case of the continuous web [1,2]. In those cases the lateral deformation and the slope of the lateral deformation of the web on a roller upstream of a test or analysis span were constrained to be zero, which required sufficient friction between the web and roller. In tests the cambered web was steered prior to web entry of the roller upstream of the test span to achieve these kinematic boundary conditions. In simulations the camber was not induced in the web until the web neared entry of the analysis span which produced near zero results for these kinematic boundary conditions. With these upstream boundary conditions for a cambered web span steady state deformation and slope resulted at the downstream roller.

Continuous cambered webs typically transit several rollers in process machines before their lateral positions would be corrected by a web guide to control lateral registration. Based on current knowledge the cambered web would continually steer toward the longer edge if the traction was sufficient between the web and rollers. The present study focuses on the lateral dynamics of a cambered belt that is transiting two aligned rollers. In this case continuous lateral motion of the web toward the long edge is observed and no zero deformation and slope kinematic boundary conditions exist. Simulation methods previously developed for the continuous cambered web will be demonstrated for a belt and verified by tests.

REFERENCES

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PREDICTING THE WEB LENGTH AND LAYERS IN A WOUND ROLL

By

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ABSTRACT

The length of web in a wound roll is one mark of roll quality. The available web length in a roll is a concern for many who process webs and those who convert webs. There are algorithms that estimate the length of web and layers in a wound roll based on simple geometry and inputs of inside and outside radius and web thickness. If webs were infinitely stiff in the machine and out-of-plane directions such calculations could be accurate but this is not the case. Webs deform as the result of winder operating conditions such as winding tension and the contact pressures and stresses due to winding. Length calculations based on geometry will err as a result of web deformation in the length and radial directions. Webs are generally subject to tension during transport through process machines, the apparent deformed web length will vary with transport tension. The mission of this paper is to describe means by which the available deformed web length and the number of layers in a wound roll can be accurately predicted. The accuracy of the predictions will be verified by winding trials in the laboratory. The winding trials will demonstrate the levels of accuracy that can be realized on laboratory and production machines.

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WEB LENGTH CREEP IN WOUND ROLLS

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ABSTRACT

The length of web in a wound roll is one mark of roll quality. The available web length in a roll is a concern for many who process webs and those who convert webs. Elastic winding models have proven very precise at estimating the numbers of layers, the web length wound into a roll and the internal roll residual stresses at the time of winding [1]. Wound rolls can spend long periods of time in storage where the environment is not well controlled due to expense. Many webs are viscoelastic on some time scale and the residual stresses due to winding will result in creep and changes in web length during storage. The changes in web length due to creep may result in web process errors and quality loss. This is often apparent where graphics or electronics may be deposited at precise intervals prior to winding and roll storage. In a downstream web process, the web is unwound and the total web length has changed and that the change is often not uniform down the web length. Thus the interval between graphics or electronics is no longer constant and results in registration conversion error. This publication will focus on the ability of viscoelastic winding models to predict these changes in web length due to creep.

REFERENCES


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ABSTRACT

Wrinkles and creases are a particular problem in thin web materials, leading to functional and visual defects. Their precursor is the wavy pattern in spans between rollers. Troughs running along or close to the machine direction (MD) are always attributed to elastic buckling from compression in the cross direction (CD). In turn, this is caused by width expansion or steering of the web edges inwards. However, the wavy pattern is also seen in sheet specimens under tension, where width contraction is expected from Poisson’s ratio. This buckling under applied tension is surprising: it was demonstrated by Friedl et al [1] that CD compressive stress can be generated in the tensile specimens with clamped ends.

This paper uses a linear elastic model for a web span with appropriate web-roller boundary conditions to demonstrate that CD compressive stresses develop if the span length is greater than 0.8 times the width, and the web enters with a CD tension. This may arise from an MD tension rise or spreading on the entry roller. If the compressive stress (assuming the web remains flat) exceeds the critical buckling stress, then troughs are expected to form. The variation of compressive stress with Poisson’s ratio, span length and width is explored using the model. Inward microslip near the web edges on the entry roller partly reduces the compression. If the span is too short to develop compression, a reduced effect may be seen in the following span if it is long enough.

An estimate shows that troughs are likely for web thickness of a few 10’s of microns and thinner, under MD strain changes of order 0.1%. Post-buckling analysis is not possible with the linear model: however, a beam analogy suggests that the web width may reduce by up to 5 times the linear calculation, and the effect propagates onto the downstream roller. This may allow some troughs to propagate as wrinkles on the roller. This mechanism should be added to the long list of possible causes of wrinkles in thin webs.
ABSTRACT

Turret winders are designed to produce batches of rolls from a continuously moving web. Typically, two spindles are mounted on a turret, 180 degrees apart. The winding roll remains in the inside (winding) position until it is nearly completed. Then the nearly completed winding roll is indexed to the outside (off-loading) position as a new core moves to the winding position. At the appropriate length, the web is cut and wrapped onto the fresh core at winding position.

While most of the roll winds in steady-state, indexing and transferring to the new core subjects the winding roll to numerous motions and changing traction points resulting in tension disturbances. The motions produce macro web length changes as the lay-on roller moves, and as the turret indexes. The incoming core contacts the web as the turret indexes. The web is nipped between the core and lay-on roller prior to the cut. The final insult is the cut and transfer of control to the inside spindle. We will discuss the impact of these disturbances on tension and roll quality. Controls to mitigate these disturbances will be suggested.
EXPLORING THE STRAIN TRANSPORT FORMULA

By

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ABSTRACT

The strain transport formula relates the velocity of a moving web to its strain. It is based on the conservation of mass which, when applied to webs, becomes the conservation of relaxed length. Simply stated it says, the velocity of a web divided by one plus its strain is a constant throughout a web path.

This paper reviews many of the useful applications of the strain transport formula. While it is commonly used for strain and tension calculations, it can also be used to optimize a web path to minimize strain or tension variation, to calculate the elastic modulus of a running web, to calculate wound-in tension at an unwind or at a winder, and many other useful things.
ABSTRACT

A roll-to-roll (R2R) printing is an emerging advanced additive for manufacturing flexible electronic devices with high throughput and low cost. As such, we have been implementing R2R gravure printing system (iPen co. Korea) to realize several electronic devices such as RFID tag, transducers, sensors, thin film transistors (TFTs), antenna and so on. In order to obtain the acceptable result of those printed devices, the printing condition of the R2R gravure system were optimized by utilizing the printing speed of 6 m/min with a web tension of 5 kgf. Despite of those optimizations, the resistance of the conducting inks based on silver (Ag) or copper (Cu) nanoparticles is limiting the performance of those R2R gravure printed devices such as antenna, thin film transistors (TFTs), diodes, and interconnecting lines. Therefore, the printed devices require a high operating voltage to compensate the power loss due to the high resistance. A convenient solution to reduce the resistance of the conducting ink based on Ag or Cu nanoparticles is to sinter at high temperature for gaining the best result but inexpensive substrates such as polyethylene terephthalate (PET) and papers cannot be used at high temperature (> 150°C) because of their low thermal stabilities.

In this presentation, the printing web (PET film) is passed through the drying chamber for thermal curing at 150°C for 5s which isn’t sufficient for Ag or Cu nanoparticle to sinter for yielding low resistance. Thus, an additional thermal curing should be carried out outside the chamber for relatively long-time duration to obtain practical device performance. That extra curing process is impractical and inefficient for all R2R process and limits the commercialization of the R2R printed devices. In this regard, a photonic curing unit which can be implemented in R2R system independently or in conjunction with the thermal curing is viewed as a viable approach to improve the conductivity of printed Ag or Cu patterns. The photonic curing with a Xenon lamp can sinter the device at higher temperature for a couple of micro seconds so that the substrate like PET and paper can be utilized. Since R2R printed patterns are in few hundred nm to 1µm range in the thickness, only the top layer will be exposed to the light of Xenon lamp for short duration without damaging the underlying substrate.
ROLL-TO-ROLL GRAVURE PRINTED SMART FOOD PACKAGE TO REPLACE THE “USE BY” DATE SYSTEM OF FOODS

By

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ABSTRACT

The current system of assessing food quality via “use by” dates needs to be replaced by a real-time assessment to prevent blind disposal of viable food products. Time-temperature history (TTH) based smart food packaging, which can provide real-time information to the consumer via smart phone at the point of purchasing, is a viable alternative to the “use by” dates. The packaging can be realized through integrating an NFC (Near Field Communication), antenna, flexible circuit board (FPCB), transponder, microcontroller, and thermistor based temperature data-logger. It is both able to monitor the temperature of food in real time and, by the way of smartphone, wirelessly send the temperature profile to the existing algorithms in order to stochastically evaluate food safety. However, the cost of TTH-smart food packaging has been a major prohibitive factor in their universal application, especially regarding low-cost, large-quantity food products. To overcome this cost issue, a roll-to-roll (R2R) gravure was employed to continuously print the smart food package platform, in which the antenna, FPCB and thermistor were integrated via all-R2R gravure printing. Instead of the “use by” system, the resulting TTH-smart food packaging then demonstrated as a real-time quality assessment of the foods through interconnecting to the provided web for determining the food safety based on the number of food-borne pathogens or other microorganisms via wirelessly transmitted TTH data of the foods.
ABSTRACT

Winding is an integral process in the manufacturing and converting of nearly all web materials such as paper, film, tissue, nonwovens, aluminum and steel. Wound rolls are the most convenient, economical, and most prevalent form of storage and transport for web materials.

Wound rolls store web materials compactly without folding or cutting. Wound rolls are a form of compressed packaging. A roll that has been wound firm enough for routine handling in a converting process has often compressed the material by more than 25%.

From a business standpoint, web materials are sold based on two broad categories:

• Geometry – Diameter, Width, Core Diameter, Roll Length, Lay flat properties, etc.
• Physical Properties – Modulus, Tensile strength, Caliper, Softness, Color, etc.

It is common to see defects such as:

• Loss of caliper in high loft webs
• Telescoping, cinching, gross internal slippage
• Large flat spots due to storage & handling
• Floppy edges and baggy lanes
• Slit width growth after winding
• Roll blocking
• Print registration shift

This presentation will explain how the material properties will determine which of two wound roll structures will result. Each of these will react differently when larger rolls are pursued. Proven methods to document your wound roll structure will be presented. Eight methods to improve your delivered quality will be offered.
INTRODUCTION

Winding failure means that the roll wrinkles or slips to lose the value of the product. Winding failure is caused by the internal stress condition [1] in the roll and the temperature change [2] of the roll after winding. Therefore, it is essential to analyze the internal stress theoretically. However, the tendency of internal stress to occur as the film thickness becomes thin is not known. The internal stress of the roll was measured at each temperature. Further changes in internal stress were also measured by changing the ambient temperature around the roll.

EXPERIMENTAL METHOD

The winding device used in this research is a structure reproducing the unwinding and the rewinding in the roll-to-roll production system. A film-like pressure sensor was used to measure the radial internal stress of the roll. After winding up the film, the internal stress in the radial direction inside the roll was measured when the temperature around the roll was heated for 12 hours. Measurement frequency was measured for internal stress every hour.

RESULT

In the PET film with a film thickness of 40 μm, the internal stress in the radial direction inside the roll was measured when the roll surrounding temperature was heated for 12 hours. For the middle and outer layers, the internal stress gradually increased with the lapse of time. It is considered that this increased the pressure by thermal expansion from the outer peripheral side of the roll. However, the value of the stress in the inner layer decreased greatly. This is thought to be caused by uneven heating due to the heat source, winding wrinkles occurred in the vicinity of the sensor sandwiched between the rolls, and stress relaxation occurred.
REFERENCES

ABSTRACT

Roll-to-Roll Nanoimprinting Lithography (R2RNIL) is a process of imprinting nanoscale patterns continuously on a moving surface. Since the patterns are continuously produced on the surface, R2RNIL has many potential advantages over batch imprinting, such as efficient mass production of large-area imprinted surfaces. In a typical R2RNIL process, a coated web is passed through the nip of two rollers with one roller surface containing the mold of the imprint pattern that needs to be transferred to the coated side of the web. In one form of R2RNIL, the coating is a viscoelastic fluid, and there are two phases of operation: (1) the mold filling phase where the coated fluid is squeezed into the mold pattern at the entry of the nip of the two rollers and (2) the curing phase where the filled fluid in the mold is cured or solidified using a heating source. Although there have been empirical observations and developments related to explaining the mold filling operation and factors that influence it, the understanding from the mechanics viewpoint on the factors affecting mold filling has not been systematically investigated. The focus of this work is on advancing this understanding by providing insights into how key process and transport parameters affect mold filling based on a model developed by the authors.

Attempts to model the mold filling process can be traced back to the problem of a squeezing flow between two solid parallel plates; the early ideas have led to a plethora of perturbation methods that were useful for understanding the basic problems of the process. Lately, more sophisticated models based on conservation laws have been developed, where the viscoelastic nature of the fluid film has been taken into account. Study of the currently available methods to investigate this problem shows that there are a number of gaps, ranging from not being able to sense the scale of the process, consideration of the free surface that is being formed inside the mold, and the evolutionary nature of the problem.

The goal of the paper is to describe the relative importance of the process, material, and transport parameters. In particular, we will employ the model to investigate the effect of web speed, fluid film thickness, viscosity, stress relaxation time, and mold pattern

EFFECT OF PROCESS AND TRANSPORT PARAMETERS ON MOLD FILLING IN ROLL-TO-ROLL NANOIMPRINT LITHOGRAPHY

By

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geometry and size on mold filling. Based on a typical imprint roller configuration, kinematic analysis, and the Conservation Laws from Classical Mechanics, we will describe the qualitative behavior of the squeezing of a viscoelastic fluid film into a rigid mold cavity. We will describe the effect of web speed and fluid film thickness on key rheological parameters, namely the Weissenberg and Deborah numbers. These numbers are typically employed to quantify viscoelastic effects in fluid flow problems. We will also discuss other scale-sensitive and geometrical parameters, such as the capillary number and the width-to-height ratio of the pattern. We will provide numerical simulations to corroborate discussions and to quantify the relative importance of the parameters.
A NEW GOVERNING EQUATION FOR WEB TENSION BY EMPLOYING A NEO-Hookean Hyperelastic Material Model

By

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ABSTRACT

In Roll-to-Roll (R2R) manufacturing, efficient transport of webs through various processes (for example, printing, coating, lamination, heat treatment, etc.) under controlled tension is crucial to ensure process quality and performance. The two key web transport parameters are web speed and tension. Models have been developed to predict the variations in these parameters spatially and temporally as the web is transported on rollers through processes under various conditions. A common approach for modeling has been to apply mass balance to the web between two adjacent rollers (web span) to obtain a governing equation for web strain where the coupling between web strain and speed is evident. Then, a constitutive relation is assumed between the web strain and tension based on the type of the material that is being transported. Various simplifying assumptions, such as small strain, length of web wrap on rollers being negligible compared to free web length in the span, etc., are made to obtain a governing equation for web tension that is amenable to analysis and model-based controller design. A particular aspect of existing modeling approaches is the utilization of different governing equations based on the value of the elastic modulus of the transported material. Because of the traction requirements on rollers to facilitate transport, often low modulus materials (such as non-wovens and certain polymers) are transported under conditions of large strains which lead to the materials exhibiting significant nonlinear behavior during transport. Whereas, high modulus materials (metals and certain polymers) can be transported under small strain which typically results in the material exhibiting linearized elastic behavior. It is beneficial to obtain a single governing equation that can be applied to web materials irrespective of the value of its elastic modulus and transport conditions.

In this work, we will describe a general formulation for obtaining a web tension governing equation that includes both linear and nonlinear elastic response of the axially moving web. This governing equation can be employed to study evolution of tension behavior within a span as well as the study of how tension variations are transmitted from span to span as the web is transported in the machine. First, we find the governing equation for stretch in a span as a function of the web speed on the adjacent rollers of the
We employ the Neo-Hookean hyperelastic material model to relate stress and stretch; the Neo-Hookean material model accounts for the deformation of both low and high elastic modulus materials, given the fact that for high elastic modulus materials the Neo-Hookean material model has the same response as its linearized version. Second, we perform a dimensional analysis and define several coefficients that aid in grouping the parameters of the machine and the web material separately, resulting in a compact dimensionless system of equations; this succinct representation can be utilized to efficiently study the impact of web and roller properties on the response. Additionally, utilizing the dimensionless representation of the governing equations, we will also discuss the stability characteristics of the transport behavior when the web machine is running under steady operating conditions, that is, under constant reference web speed and tension.
WEB LATERAL POSITION REGULATION USING SPATIALLY DEPENDENT TRANSFER FUNCTIONS

By

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ABSTRACT

Focused studies on modeling the lateral behavior of moving webs goes back to at least the 1960s. The first comprehensive work was reported by Shelton in his PhD thesis in 1968, in which the moving web between two rollers is treated as a static Euler-Bernoulli tensioned beam. Four boundary conditions (web lateral position and slope on each roller) were considered to solve the ordinary differential equation describing the web lateral web position as a function of spatial distance along the span. Additionally, a key observation/principle that is prevalent in the transport of belts literature was employed to describe how the web approaches the roller at the entry of the region of wrap; that is, a belt approaching a roller aligns itself normal to the axis of rotation of the roller. This normal entry principle was employed to develop two normal entry conditions, one for velocity and one for acceleration, at the entry of the web wrap on the roller. Most of the subsequent work in the area used this approach and derived transfer functions from the guide roller position (input variable) to the web lateral position on the guide roller (controlled output variable). A key deficiency of existing approaches is that one can only obtain the response of the lateral web position behavior on the roller. Recently, Cobos and Pagilla (2018) developed a method to obtain spatially dependent transfer functions which were utilized to obtain the response of web lateral position and slope at any point within the web span and on the rollers. These spatially dependent transfer functions can be employed to predict lateral behavior at any point in the web span due to guide roller movement and propagation of upstream disturbances, as well as to control the lateral position within a span and on the roller.

In this work, we employ a non-dimensional state space representation of the spatially dependent transfer functions to study fundamental properties of lateral system of equations with lateral displacement and rotation of the guide roller as inputs. In particular, we will show that controlling web lateral position and slope requires independently controlling the rotation and translation of the guide roller. Since measurement of web slope at any point in the web span cannot be readily available using existing sensors, we will discuss how the spatially dependent lateral model and
measurement from two edge sensors can be utilized to obtain an estimate of web slope. We will discuss appropriate location of the two edge sensors based on model analysis. We will also discuss control strategies for controlling both web lateral position and slope and attenuation of upstream lateral disturbances. We will provide results from extensive numerical simulations of representative guiding setups to support the developments and discussions. This study is particularly relevant for high-precision lateral regulation within the span that may be required for emerging R2R applications in flexible and hybrid electronics such as nanoimprinting, printing, and deposition processes.
This paper focuses on control methods used in the Rockwell Automation drives of the Euclid Web Line system in the Web Handling Research Center at Oklahoma State University, and how the control methods affect the performance of the system. The Euclid line has five control zones – unwind roll, s-wrap lead and follow rolls, pull roll, and rewind roll – and seven total controllers. Each controller uses Proportional plus Integral Control. The controllers in the unwind and rewind zones use a speed feedback inner loop and a tension feedback outer loop (see figure below). Tension is measured with load cells. The outer tension loop provides a correction to the speed reference in each case. The other three control zones use simple speed controls. Roll speed is measured with rotary encoders in all five rollers. During an unwind-rewind operation, the unwind and rewind roll inertias vary with respect to time and the controller speed gains are continuously updated. The tension loop gains are held constant.

Linearized models of the Euclid Web Line are developed for two cases: (1) fixed gains in the tension loops and speed loops in the unwind and rewind controllers, and (2) fixed gains in the tension loops and variable gains in the speed loops based on time varying inertias of the unwind and rewind rolls. The second case is implemented in the Rockwell Drives on the Euclid Web Line. Simulations show that for large changes in the inertias, the variable gain approach results in better system performance than that with a fixed gain approach. Results of experimental studies with the fixed gain and the variable gain approaches are presented to validate the findings of the simulations.
ABSTRACT

Web handling processes consider slip between a web and a roller as a defect. Slip can cause surface scratches which can be detrimental to a product, if not catastrophic. As line speeds increase to meet demands for more product per unit of operating time, the likelihood of slip increases. Slip may be partial or total, or a combination of both. In this paper we consider total slip only, i.e. slip over the entire area of contact between a web and a roller.

Whitworth [1] defined criteria for when full slip initiates, and developed a model for how slip affects the tension in the spans on either side of a roller where slip occurs. A Sliding Friction Driven Roller (SFDR) model is developed in this paper. This model uses the Whitworth criteria and span tension model. Both models use the Capstan equation to determine if slip is occurring. With the Whitworth model, the torque which drives the roller is due to the tensions in the span on either side of the roller, but with the SFDR model the torque which drives the roller is due to sliding friction between the web and roller.

The Euclid Web Line (EWL) in the Web Handling Research Center at Oklahoma State University was used to study slip both analytically and experimentally. A dynamic model of the EWL was developed. Measured physical characteristics of the elements in the EWL were used in the analytical studies. Simulations with an industrial ramp showed that the Whitworth model is valid when the web and roller are moving at almost the same speed (up to a difference of about 50 FPM). Moreover, simulations showed that the SFDR model covers the total slip situation when the tangential velocity of the roller and web velocity are distinctly different (more than a 200FPM difference). The simulations also showed that the torque due to bearing friction at a roller had to be equal to the torque due to difference in tensions in the spans on either side of the roller in order for the initiation of slip to occur.

Simulations showed that for slip to happen on the Euclid Line, the web speeds would have to be greater than the Line could attain (1200 FPM vs. 500 FPM). In the experimental studies, a parasitic torque was applied to a roller mounted on load cells to...
create a slip condition. Hanging weights were used to apply the parasitic torque. An encoder was mounted on this roller to measure rotary velocity of the roller. Results from the experimental studies showed that the Whitworth model was valid only when the parasitic torque was small (up to about twice the bearing friction induced torque of the worst bearing on the Euclid line. In contrast, experimental studies showed that the SFDR model was valid only when the parasitic torque was large (about four times or more of the torque induced by the worst bearing in the EWL and up). A model is needed to cover the entire spectrum. Such a model is expected to be heavily dependent on the contact mechanics between the web and the roller.

REFERENCES

ABSTRACT

A web line may have several control systems to control web speed, roller speeds, and web tension. In this paper a specific web line with multiple sections, referred to as the Euclid Line, is considered. The sections include an unwinding section, a process section, and a rewinding section. A pull roll establishes the web speed. There are five speed controllers, and two tension controllers. Proportional (P) + Integral (I) Controllers are assumed throughout the web line. A linearized dynamic model of the Web Line is developed to facilitate simulation. The model includes numerous physical parameters and P & I gains for each of the seven controllers. A systematic method for finding the controller gains is the primary objective of this paper. The method involves first simplifying the model for each section using a Routh Approximation, and then determining the controller gains based on selected performance criteria. Experimental studies on the Euclid line with the determined gains are presented.
A TAXONOMY OF WEB AND WINDING DEFECTS

By

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ABSTRACT

Constructing taxonomies can be useful for the researcher and troubleshooter alike. First, it gives us a precise language for conversation within our own plant or with our customers. This language helps us avoid using the same word for two different things or using two different words for the same thing. Examples of word confusion are corrugations versus tin-canning as well as telescoping and coning. Second, taxonomies allow us to make crucial distinctions between similarly appearing defects, but whose mechanics and thus remedies may be quite different. Examples include a wrinkle oriented at an angle means something (roller, web etc.) is ‘crooked,’ while the root cause mechanics for a wrinkle oriented in the MD may have something to do with width.

As useful as good taxonomies might be, they can be exceedingly difficult to do well. Very often they are a work in progress. They are always part craft and part science. On the craft end we might offer as an example the troubleshooting trees used by automobile mechanics to identify which part needs to be adjusted or replaced to get an engine running. On the science end we might offer the classification of life forms which used to be based entirely on form and is now being based on DNA, when it is available.

In this paper we will show how to construct taxonomies for some common defects. While good taxonomies are mechanics based, these mechanics and the attendant complexities should be hidden from the user to the extent possible. The goal is to be able to do most everything observationally rather than requiring equations or instruments because it greatly increases the utility of the system. However, the researcher can also use a good taxonomy because it is mechanics based. In any case, everyone can benefit from a precision of language. The defects we will include here are most forms of web flatness/wrinkling as well as some winding defects such as core crush, starring and telescoping.
ABSTRACT

Avoidance of web handling-related imperfections is often a challenge. As an example, the limit of web-to-roller traction is typically not detected until it is exceeded, resulting in product damage. Detection is often made through product inspection. This delay can result in a large volume of unacceptable material being produced. Inclusion of roller speed monitoring can greatly improve response time, but detection still occurs after failure has been initiated.

Avoidance of traction problems is normally approached by providing robust equipment design, although this ability is often limited by other machine layout limitations. Variables that can influence web-to-roller traction include: roller wrap angle, roller surface roughness, web surface roughness, bearing frictional drag, roller venting, boundary layer air volume, track-off of foreign materials onto roller surfaces, wear of roller surfaces.

Measurement of web-to-roller traction, often described as excess traction, requires a pre-determined amount of torque to be applied to the roller until the onset of slip. This paper describes an approach which incorporates multiple remote-actuated, machine-mounted prony brakes and a process verification (PV) system, which would permit rapid measurement of excess traction on a routinely-scheduled basis while running non-saleable material, enabling traction performance to be trended, anticipating failures before they occur on saleable product.

Incorporating targeted measurement data into a PV system will permit calculations and comparative controls to alarm when there is evidence of traction deterioration. This system could provide machine learning algorithms to predict process deterioration and provide input to preventative maintenance scheduling.
ABSTRACT

Most manufacturing processes are inundated with tremendous amount of information from various sensing and measurement devices. Most of the information is consumed by feedback controllers or PLCs for specific purposes. For example, the edge sensor data is typically used for web guiding or lateral position control of the web. However, this information is seldom used for other purposes. In this paper, a few examples on how data produced by common sensors and actuators can be used to identify anomalies in the processes. Further, development of models for the real-time anomaly detection will be presented with experimental data.
ROLL VARIABILITY ANALYSIS FOR NON-STATISTICIANS

By

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ABSTRACT

Roll variability can be characterized by several different methods. Off line cross-direction (CD) scans of thickness or coat weight for example give a snapshot of CD variation over a small machine-direction (MD) range. Roll hardness profiles have long been used to evaluate web uniformity in wound roll form – particularly for flagging potential web bagginess. Roll hardness profiles are easy to measure, but a strong correlation to roll quality depends on having a somewhat stable CD thickness or coat weight profile and relatively low MD or time variation.

Summary statistics from in-line scanning gauges (mean, range and standard deviation) sample the entire roll, but don't describe the distribution or location of the variation. 2D contour plots are helpful for visualizing roll variation, but alone aren't enough to translate that variation into a useful specification.

Since specification limits for good web processing are often much tighter than limits for good end use function, making the best use of scanning gauge data is helpful for efficiently focusing process improvement efforts. Analysis of Variance (ANOVA) is able to evaluate the uniformity of a web property (thickness, coat weight) from an inline scanning gauge and partition the roll variance in the MD and CD directions.

This paper shows how the combination of ANOVA and contour plotting can be used to both quantify and visualize roll variability within and between rolls in order to drive web uniformity improvement.
DEVELOPMENT OF R2R DIRECT GRAVURE COATER AND LAMINATE SYSTEM FOR POUCH BATTERY OF ELECTRIC VEHICLE

By

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ABSTRACT

Li-polymer battery is used in various industries such as electric vehicles and ESS. This battery has pouch type package, so it allows the Li-polymer battery to be thinner and lighter. The packaging material is Al pouch film that is composed of a metal and polymer films. Each film is laminated via urethane-based or polyolefin-based adhesive. We developed the Al pouch by applying Roll-to-Roll dry lamination using gravure coater. Roll-to-Roll dry lamination is a process in which the adhesive is directly coated on the film and then the second paper is laminated by heating, thereby simplifying the process. Also, the gravure coater is not affected by variable such as roll pressure. It has coating accuracy, so yield and production seed are improved.

The Al pouch is essential that the adhesive strength between the adhesive and the films is stable and that the electrolyte resistance is stable against the electrolyte. We applied Roll-to-Roll dry lamination to set up process conditions with the aim of achieving the same physical properties as world class. (ref. adhesive strength & electrolyte resistance : 10N/15mm or more). Through the process conditions such as temperature, pressure and speed, we have developed products with adhesive strength of 11N/15mm or more and electrolyte resistance of 10N/15mm or more.

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