On the Governing Equation for Web Tension with Out-of-Round Rolls

Article

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Abstract

In roll-to-roll (R2R) manufacturing the presence of non-ideal elements, such as out-of-round or eccentric rolls, induces periodical oscillations in the web tension signal. Model simulations based on ideal elements do not exhibit these tension oscillations but can only follow the measured tension signal in an average sense. In order for the models to predict these measured tension oscillations due to non-ideal elements, the derivation of governing equations must consider a mechanism to include the correct behavior of the non-ideal transport elements. Continuing with our previous work on this topic presented at previous IWEBs, we present additional results that provide improvements to the web span tension governing equation which can better predict measured tension signals. In particular, this work is useful for tension control in the unwind section of the web line when the unwind material roll is often out-of-round. The governing equation for web span tension is typically derived using the law of conservation of mass by considering a control volume enclosing the web span, i.e., at any instant of time the variation of web mass in the control volume is equal to the difference of the incoming and outgoing material flow rates. If the web span is between two ideal elements the only way to induce changes in web span tension is with an imbalance in the web material flow. For ideal elements it is easily shown that the material flow rate is proportional to the difference of the peripheral velocities of the web on the surface of the rolls adjacent to the web span. When an out-of-round roll is at one end of the web span, two aspects make the derivation of the web tension governing equation different from the ideal case. First, because of the out-of-roundness of the roll, the span length adjacent to the roll is time-varying; variations in the span length induce web tension variations that are not associated with an imbalance in material flow. Second, the material flow rate is not proportional to the peripheral velocity of the web on the out-of-round roll and must be computed explicitly. Given a measure of out-of-roundness of the roll, due to the complexity of the problem it is difficult to derive a closed form expression for the material flow rate as a function of the roll position and velocity. A numerical algorithm for the computation of the material flow rate is presented in the paper. Based on the computation of the material flow rate and the algorithm for the computation of the span length adjacent to an out-of-round roll which was presented in the previous

IWEB, a new governing equation for web tension is developed. Using this new governing equation a dynamic model for an experimental web line is developed and model simulations are conducted. To corroborate the model, experiments are conducted on the web line with an out-of-round unwind material roll. Comparison of the results from model simulations and experiments are presented and discussed.