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Ultra-Precision Control of a Reel-to-Reel Process

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Introduction

The US Department of Energy describes reel-to-reel processing as “a family of manufacturing techniques involving continuous processing of a flexible substrate as it is transferred between two moving rolls of material” [1]..Research has recently been conducted in adapting the production of Organic Printed Electronics (OPE) and Organic Photovoltaics (OPV) to reel-to-reel processing in order to take advantage of its lower production costs. These devices consist of up to 5 layers and require a separate printing or coating process for each. The location of the features on the previous layer must be determined and the position of either the web or the printer adjusted before a new layer is added. As the R2R process is continuous, the control system must be able to continuously measure the previous printed layer and then carry out any adjustments required. In order to achieve this, advances are required in three areas:

i. Control of the web;
ii. Measurement and registration of the printed web; and
iii. Flexible, semi-conductor materials.

The research will initially control and measure the accuracy of the process during a single print run. Once this has been achieved, a second layer will be printed. Successful completion of this stage will enable further research into the measurement and control of multiple webs in a lamination process.

Cranfield Reel-to-Reel Development Platform

The Cranfield Reel-to-Reel development platform consists of an Unwind Roller, a Coating Drum, a Gravure drum and a Rewind Roller. The Unwind Roller carries the web prior to processing while the Rewind Roller collects the web after processing has been completed. A lacquer is applied to the web as it travels around the Coating Drum. The Gravure Drum is an engraved cylinder that carries the pattern which is to be imprinted in the lacquer. Other rollers are included where necessary to guide the web between processes..

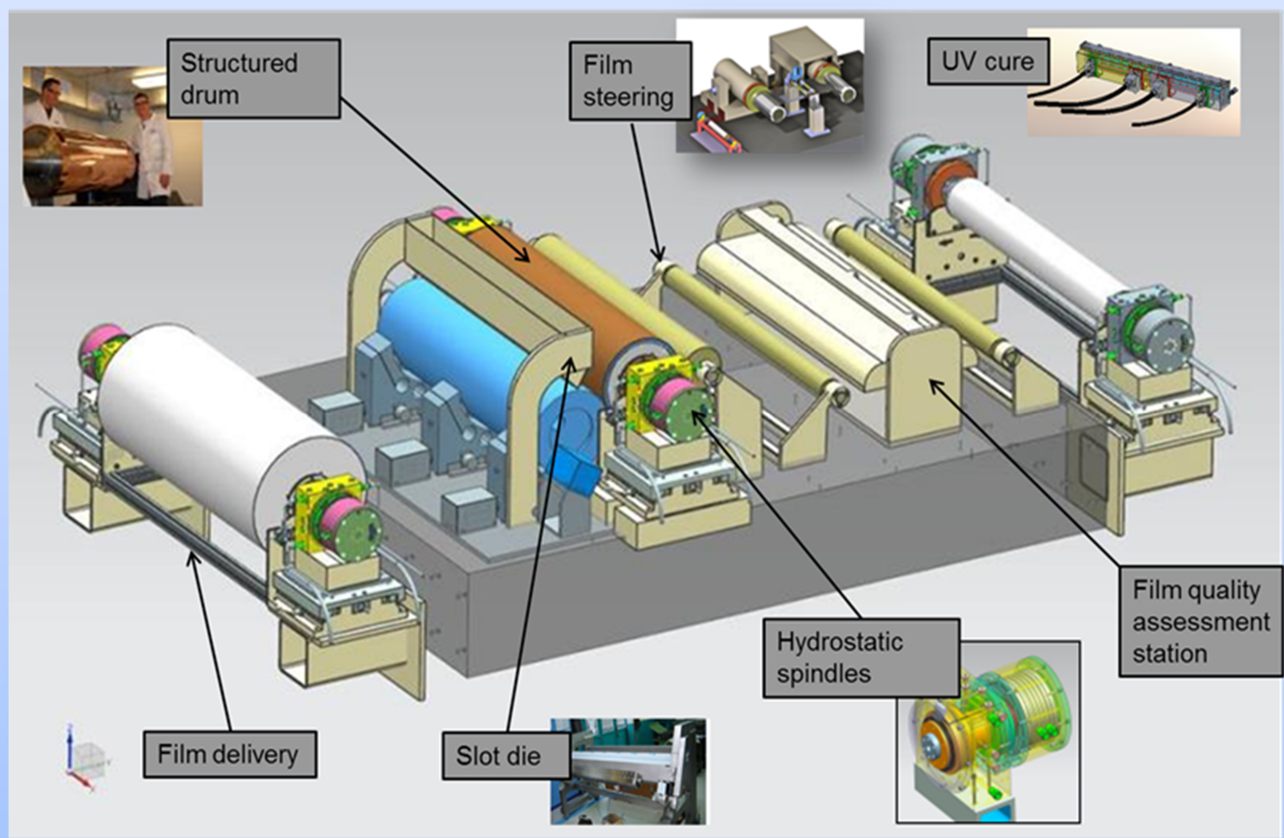

Figure 1: The Cranfield R2R development plant

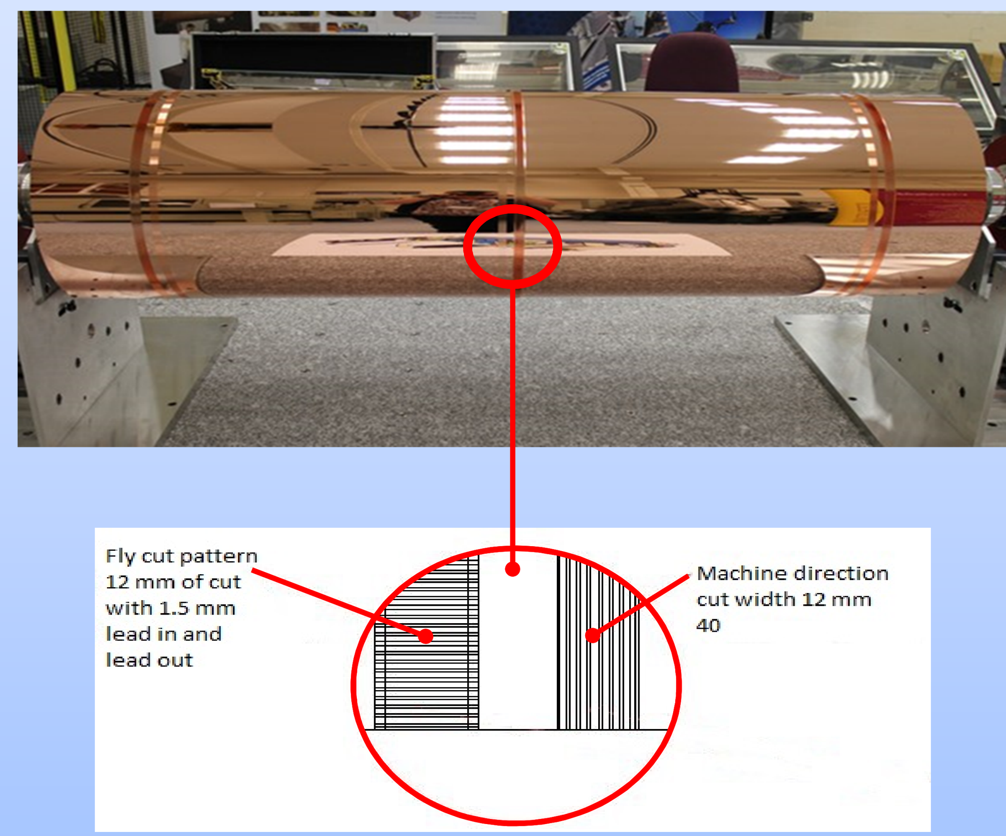

Figure 2: The Gravure Drum pattern

Metrology Station

A linear optical encoder is under development by Cranfield University and NPL. This will provide real-time web position data.

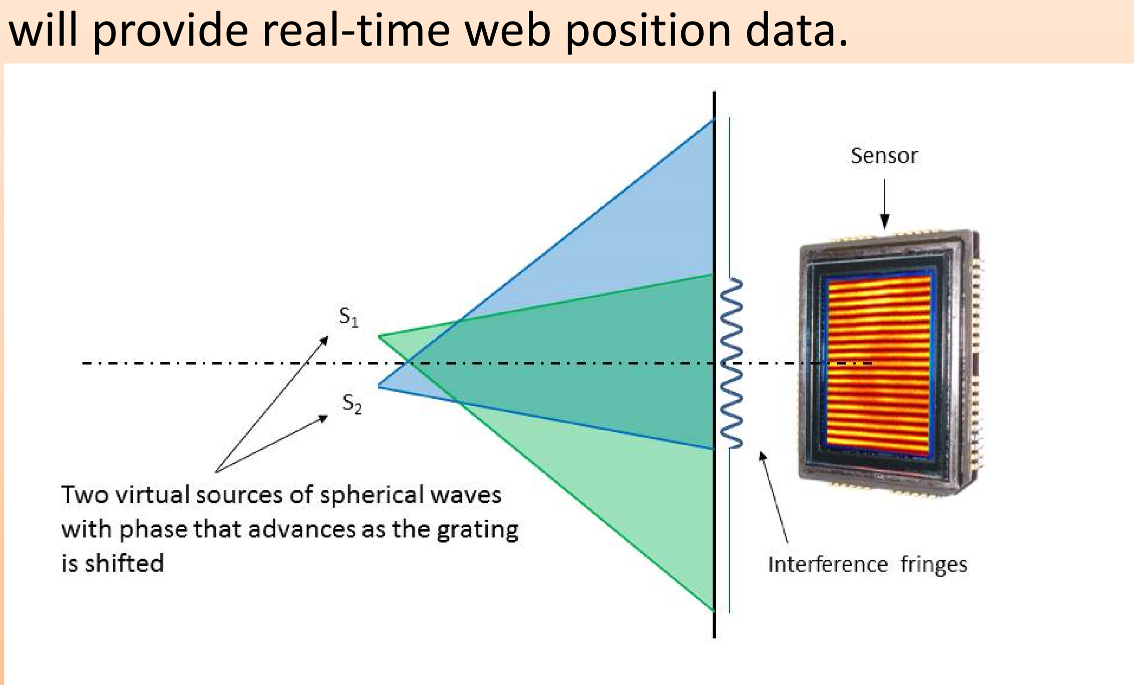

Figure 3: Principle of operation of the NPL linear encoder [2]

Simulink Model

A two webspan R2R plant was modelled using Simulink. Web speed was controlled by the angular speed of the Gravure Drum (GD). Tension T2 between the Unwind Roller (UW) and the Gravure Drum was controlled by varying the Unwind Roller speed. Similarly, Tension T3 between the Gravure Drum and the Rewind Roller (RW) was controlled by varying the angular speed of the Rewind Roller. The relationship between the web tension and the linear velocity of the web is given by

$$L \cdot \frac{dT_2}{dt} \approx E \cdot A \cdot (V_2 - V_1) + T_1 \cdot V_1 - T_2 \cdot V_2$$

Equation 1: Relationship between web velocity and tension [3]

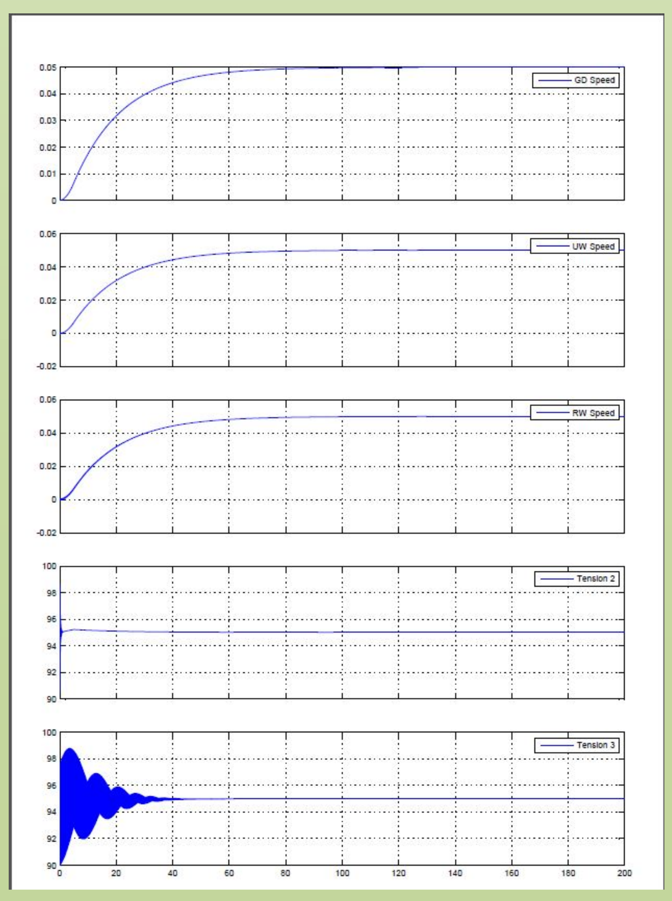

Figure 4 (a): Roller speeds and webspan tension with the GD controller proportional gain Kp = 1

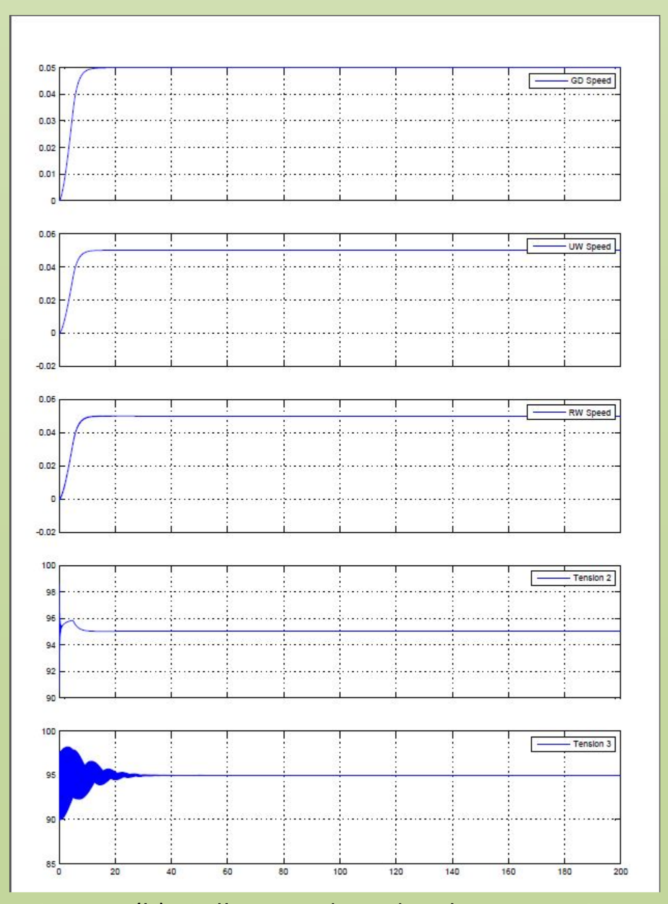

Figure 4 (b): Roller speeds and webspan tension with the GD controller proportional gain Kp = 10

References

[1] US Dept of Energy *“Roll to Roll (R2R) Processing Technology Assessment”* 2013

[2] Hollstein K, O’Connor D, Jones C, Morantz P, Comley P (2016) Implementation of a linear optical encoder for high precision in line position referencing of plastic film in a Roll-to-Roll system. In: Innovations in Large-Area Electronics (innoLAE 2016), Cambridge, UK, 1.02.2016-2.02.2016; 67-68.

[3] Young, G.E. and Reid, K.N. (1993) ‘Lateral and longitudinal dynamic behavior and control of moving webs’, *Journal of Dynamic Systems, Measurement and Control, Transactions of the ASME*, 115(2 B), pp. 309–317.

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