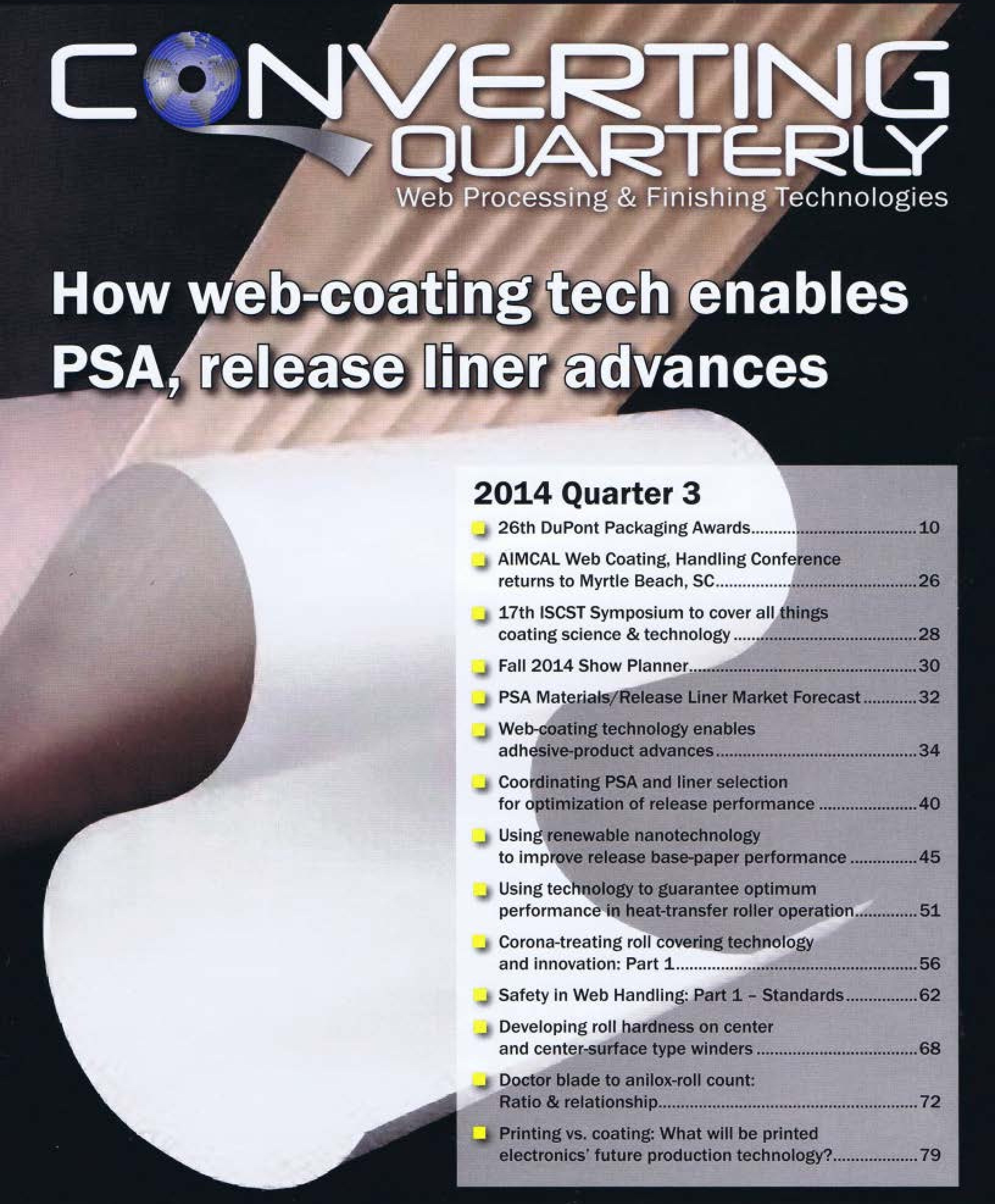
CONVERTING QUARTERLY
Web Processing & Finishing Technologies



How web-coating tech enables PSA, release liner advances

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Using Technology to Guarantee optimum perforormance in heat transfer roller operation

By Matthew Menges, President, and Jeffrey Awe, Marketing Director, at Menges Roller Co., Inc.

Editors Note: *This paper describes the 2014 AIMCAL Technology of the Year Award Winner. The Computational Fluid Dynamics (CFD) Thermal Modeling Process also earned Finalist status in the Coating/Laminating Equipment/Accessories Category*

Introduction

Have you ever experienced not enough? Maybe it was last season's dreaded Christmas lights blowing fuses from not enough power. Maybe it's that smartphone battery that is all-too-often running out of juice. What about too much? Fun in the sun is nice, but it gets a little uncomfortable past 100°F.

These examples have fairly minor repercussions. But consider the implications in talking about heat transfer and chill rollers. What if there's not enough heat emanating from a heat transfer roll on your laminating line? And the ramifications would be equally negative if a chill roll isn't cooling your substrate enough, slowing production to a snail's pace.

Reliance on accurate, uniform and predictable thermal transfer has never been greater. But many converters still rely on outdated schematics, incorrect engineering formulae or "educated guesses" to decide heat transfer roll dimensions and design details.

What should the new flowrate be, considering the linespeed just increased by 20%? Should the roller really be running water, or would glycol be more effective? How large should the heat transfer roll be to achieve 330°F across an 8-ft-wide web of three-layer laminated film?

We're often times just "half sure" we know the answers to these performance questions. And the stakes are pretty high. Spending tall cash on a chill roll that doesn't work properly is a waste of company funds and a potential career killer.

But risks like these are unnecessary. In the hands of the right engineer, advanced technology can now "virtually" simulate a heat transfer roll's performance in a converting operation, allowing engineers to see - on a computer, before the roll is built - the temperature the roll will achieve, the temperature variation across the rollface and even the effect the roll will have on the web & its coatings. And if the heat transfer roll's initial design doesn't generate the desired temperature profile, engineers can simply use software to modify the roller's interior cavity dimensions, increase or decrease journal bores, or revise the spiral wrap angles – until the roller finally achieves the desired thermal profile and performance signature.

Big Data

This technology is known as Computational Fluid Dynamics (CFD). What makes CFD so powerful is its ability to incorporate laws and principles from multiple disciplines – from thermal dynamics and fluid mechanics, to chemical engineering, motion sciences, and metallurgical principles – into one complex engineering equation that generates a reliable, easy-to-decipher, bottom line picture of what will happen in a converting line when using a heat transfer roll of this or that design (see Figure 1).

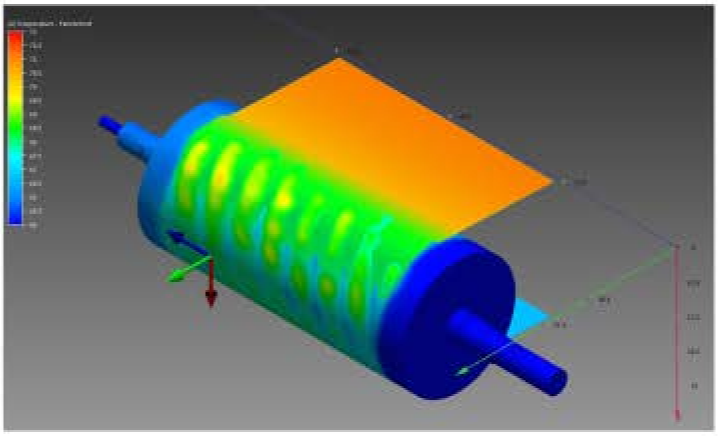

FIGURE 1. *Not that long ago, converters and roll makers attempted to make design conclusions using a series of long and complex equations that incorporated thermal, chemical, fluid and motion sciences. Today, these equations can be completed with CFD Thermal Modeling Technology.*

If an engineer changes, for example, the wrap angle on a chill roll's spiral baffle, a good CFD Model will show the revised temperature across the rollface, the revised fluid pressure data, turbulence data, and how all these sub-factors come together

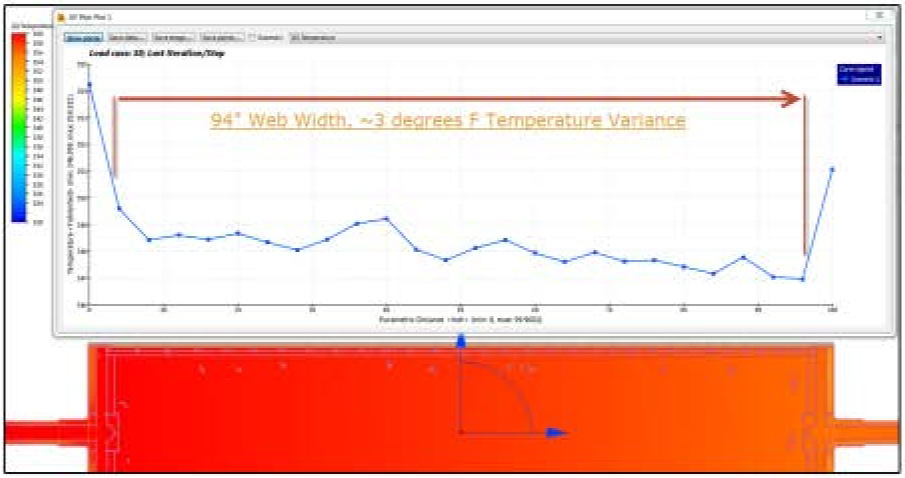

FIGURE 2. *CFD thermal modeling generates a significant amount of data and informative charts. What matters for heat transfer rolls is the ability to achieve a low temperature variance across the rollface. This roll's 3° temperature variance required several iterations to achieve, each version making small modifications to key components.*

- **Rollface Diameter**
- **Journal & Collar Properties**
- **Fluid Cavity Dimensions**
- **Spiral Baffle Angle**
- **Properties of Steel Grades**
- **Rollface Finish/Chrome Properties**
- **In-Feed & Siphon Tube Capacities**
- **Rotary Union Specifications**
- **Linespeed & Roll Rotation Speed**
- **Thermal Fluid Chemistry**
- **Temperature of Thermal Fluid**
- **Flow Rate of Thermal Fluid**
- **Fluid Cavity Pressure**
- **Substrate Chemistry**
- **Web Thermal Properties**
- **Web Dimensions / Thickness**
- **Temperature of Web at Entrance**
- **Target Temp/Change in Temp**
- **Ambient Air Temp & Humidity**
- **Coating & Dry Time Factors**

TABLE 1.
CFD Models are known for the ability to consider every concievable factor: fluid-related, thermal, mechanical, motion, metallurgic, and more.

affect the laminating process. If the roller is made from 316 stainless steel instead of 304, how will that affect my temperature? CFD models can tell you. How much colder or hotter will the roll get if its rotation is increased by 50 RPM? CFD applications can easily answer these questions.

The power of CFD Thermal Modeling technology makes it possible to design heat transfer rollers with a degree of accuracy and surety by which it can virtually guarantee that the roll will accurately meet the target temperature and maintain required temperature variance factors. Along the path to achieving the perfect performance signature, there may be a fair amount of trial and error – modifying components and measurements until you get what you want – but it all happens at the engineer's workstation, not in the roll manufacturing shop.

CFD Models also generate detailed, color-coded images that completely map the roll from one end to the other – showing precisely, in a visual way, how much hot or cold energy the roll will generate, how much of that energy will be distributed to the substrate, and the final temperature changes in the web (see Figure 2). Temperature variations - broken down to fractions of a degree - are noted across hundreds of data nodes along the rollface and the web.

Modeling Impact on Ancillary Equipment

Another benefit of being able to consider every design factor is that specifications for ancillary equipment, such as pumps and rotary unions, can be examined. And the new heat transfer roll can be built to compensate for shortcomings in existing chillers and pumps. The plant gets that "just right" thermal transfer to the web without having to rebuild the entire converting station. CFD can allow engineers to keep their exiting chillers, pumps and related bits of equipment.

Where This Technology Fits In

Computational Fluid Dynamics is not necessarily a new field of study, and increasingly powerful hardware and software have made this technology more accessible and accepted in several fields. What we describe here is a relatively new use of this technology in the converting sector. The aerospace industry and NASA have used CFD models for years to simulate the mixed dynamics of airspeed, atmospheric resistance, heat generation, and material strength. Certain medical sciences have also embraced CFD-based simulations.

For the converting industry, the idea is to design a heat transfer roller or series of rolls that meet the plant's thermal requirements – achieving a select target temperature, maintaining it over long production runs, with minimal variation across the rollface - usually no more than +/- 2°, all while not "over-engineering" or "under-engineering" the roll (see Figure 3).

Overdesign is prominent in the converting industry, as many rolls are designed larger than required, or 2-3 thermal thermal rolls are used where one really effective roll would be better.

More rolls means higher initial costs, higher maintenance costs and a tougher line to keep running efficiently. Dreaded under- fabrication is also avoided with the correct use of CFD Modeling. With under-engineered heat transfer rolls, the converter is forced to increase dwell time - the amount of time the web contacts the roll - which basically means slowing production. Quite simply, without the use of powerful software to design process heat transfer rolls, the converter risks paying extraordinary costs in over-fabrication or under-fabrication.

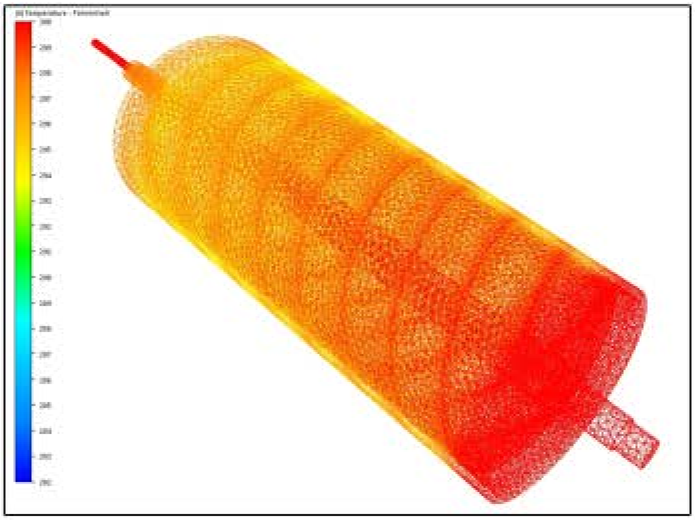

FIGURE 3. *Hundreds of nodes along the rollface note exact temperatures externally and in the internally cavity of the roll.*

Strength Testing

To ensure a roll's strength and load-bearing profile meet exact requirementes, engineers can mix in a technology known as Finite Element Analysis (FEA). Often used in conjunction with CFD, FEA simulations generate detailed data and images to accurately dissect which parts of the roll will incur the most stress when loaded (usually the shoulder area, where the journal meets the endplate). The engineer can then test and re-test the capacities of components made from various grades and thicknesses of steel, stainless steel or aluminum until they arrive at the optimal balance of strength and functionality.

In today's converting plant, stress testing is actually more important than ever. With faster linespeeds, higher pressure nip systems, and 24-hour operations, factors such as deflection and centrifugal force represent ever-present stresses that will quickly breakdown an under-engineered roller.

On the other hand, every roll cannot be such a behemoth that it causes mounting or maintenance issues. As noted previously, we want a balanced design, not "not enough" and not "too much." In the hands of a skilled engineer, FEA is useful in finding the proper balance of size and strength (see Figures 4 & 5).

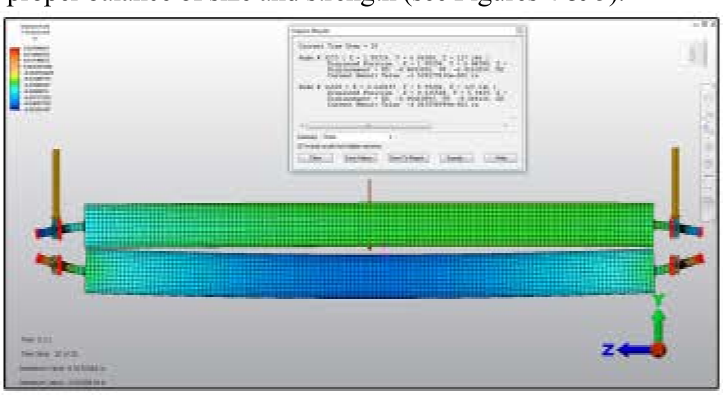

FIGURE 4. *Using FEA to test the strength of journals under pressure in a tightly-compressed nipping system.*

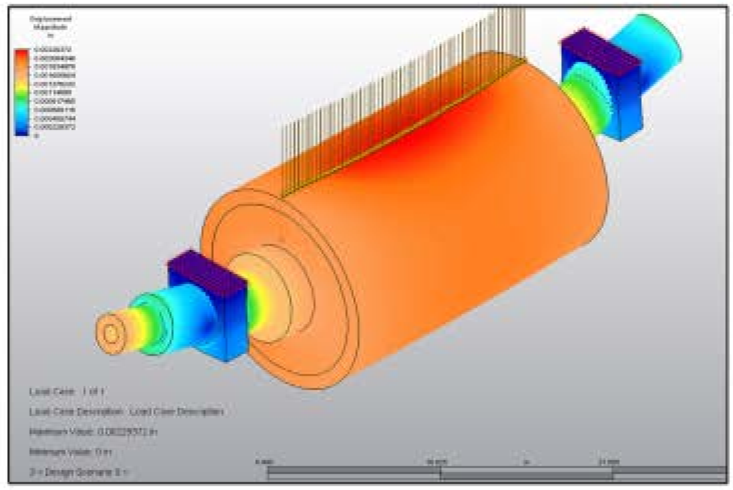

FIGURE 5. *A heat transfer roller being stress tested iusing FEA. Core & journal strength can be measured with great accuracy.*

Conclusion

Computational Fluid Dynamics and Finite Element Analysis are complex tools, but their purpose is simple: eliminate guesswork. This saves time and money (for the rollmaker and converter) and helps ensure heat transfer rollers perform at a high level over a long lifespan.

This firm uses CFD and FEA technology to design heat transfer rolls that perform exactly as modeled in the lab, exactly as our customers – converters, extruders and laminators – need these rolls to perform. And with today's complex converting processes, "close enough" just doesn't cut it. Tolerances are tighter than ever, adhesive temperature ranges are tighter than ever, and laminators just keep adding layers.

But, especially with CFD Simulations, the sheer number of options and input factors can be daunting for an uninitiated engineer. A solid footing in engineering principles and terminology is required, along with field-based "cause & effect" knowledge. Technology can show what the results of a design modification will be, but there's no one button for "build me the perfect chill roll." Additionally, a certain level of up-front data gathering is required before reliable heat transfer simulations become plausible. The more data points you can complete, the more accurate your final simulations will be. Lastly, no matter what the process or component being modeled – heat transfer roll or next-generation space shuttle – CFD and FEA systems should be tied to a high-performance 3-D CAD system.

It's definitely a lot to bring together. But the positive results take the form of rollers and components that are fully-tweaked to perform at a very high level. For the converting plant, this means a reduction in 'trial and error' and a higher level of reliability over a longer period of time. This technology ends the 'too much' and 'not enough' dilemma. When performance counts, get the design right the first time. ■