TECH 42 – Technical Seminar Speaker

NEXT GENERATION EQUIPMENT FOR THE PRECISION COATING OF PERFORMANCE FILMS, FOILS AND PAPERS

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Richard Tippett studied Chemistry and Computer Science at Victoria University and graduated in 1986 with a B.Sc. (Chemistry major).

From 1986 – 1989 he worked for Shell Oil NZ in quality Control.

From 1990 he worked in Technical Development at Cerestar Deutschland (now Cargill), a leading starch manufacturer. In 1997, he joined the Application Centre Paper, applying alternative binder systems to paper coatings, with special focus on tailor-made surface properties for offset and digital printing. In addition to this, he led a paper testing laboratory, analyzing printing and coating defects, identifying the root causes and providing solutions.

In 2014, Richard joined OLBRICH as a member of the Development & Process Technology Department. He is responsible for the planning, supervision and evaluation of pilot trials in the fields of coating, laminating & embossing.

Next Generation Equipment for the Precision Coating of Performance Films, Foils and Papers.
… Including practical examples

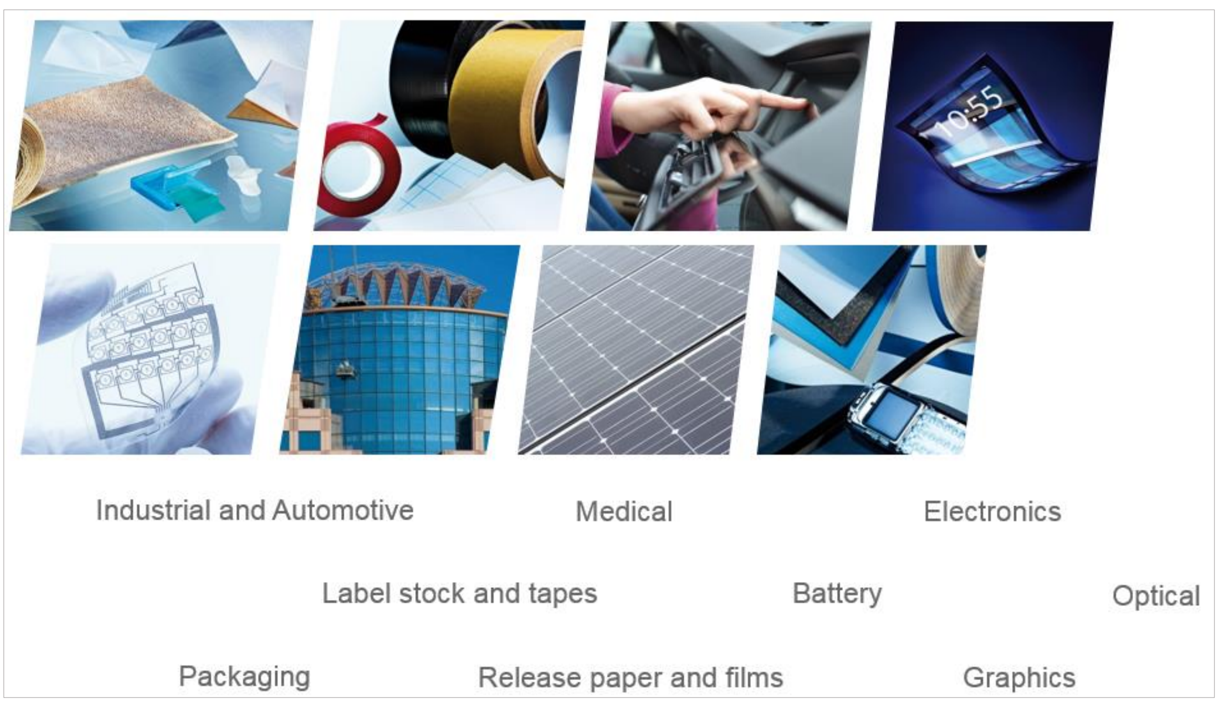
Richard Tippett, Olbrich GmbH

Recent years have seen a strong upsurge in the use and diversity of coatings. As demands for high-tech products have increased, the coatings have undergone huge development.

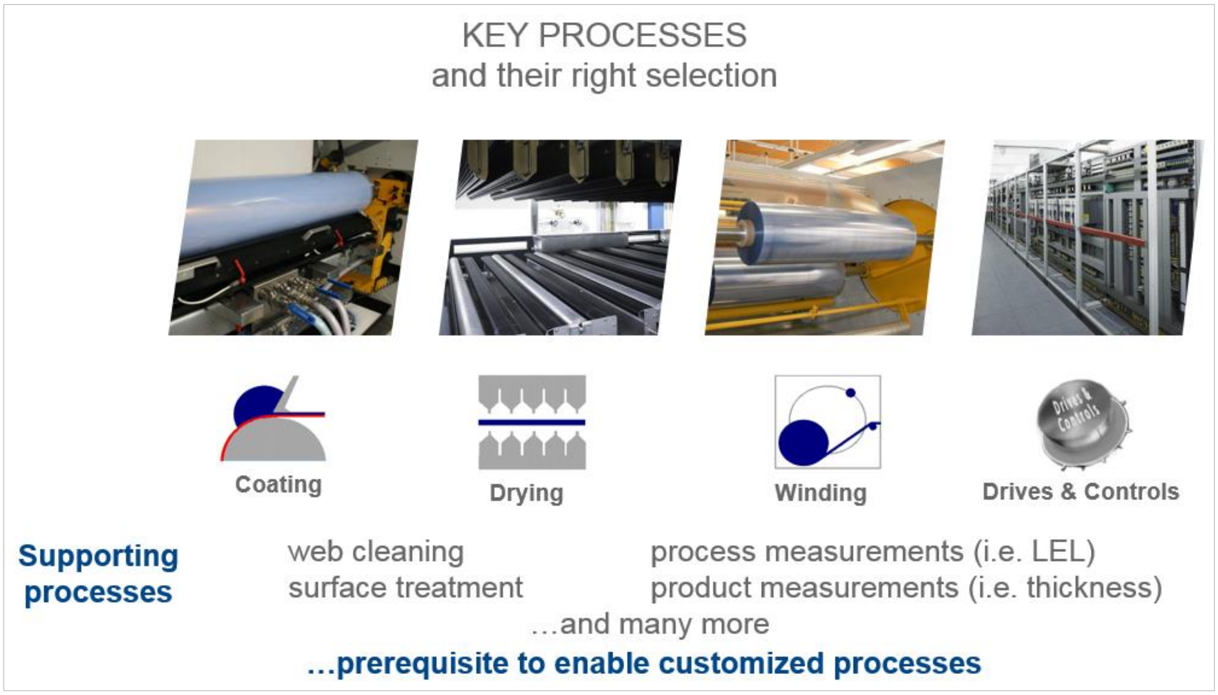
Coatings themselves are normally very thin, but change the surface properties of the substrate vastly. The purpose can be functional, decorative, or both. At the drop of a hat, piano lacquer-type surfaces can be made to withstand scouring with steel wool by adding nanoparticles to the polymer coating. Paper can be coated with polyurethane-based soft coatings to impart leather-like haptics. Graphene enables films to become electrically conductive while remaining transparent, expanding the possibilities of printed electronics. The assembly of consumer goods has become unthinkable without the use of modern pressure sensitive adhesives, and developments indicate these will be electrically "switchable" in the future, to facilitate de-bonding and recyclability.

The high demands on quality coatings directly translates to their homogeneous application onto the various substrates. This is where the challenge begins for the coating operations. As a chain is only as strong as its weakest link, we must therefore possess the necessary competence at every stage of the coating process to guarantee reliable performance of our final product.

The high-end products for which solutions are necessary encompass diverse sectors such as Industrial & Automotive, Medical, Electronics, Battery, Optical, Packaging, Graphics, and last but not least Label Stock & Tapes and their counterpart Release Paper & Films.

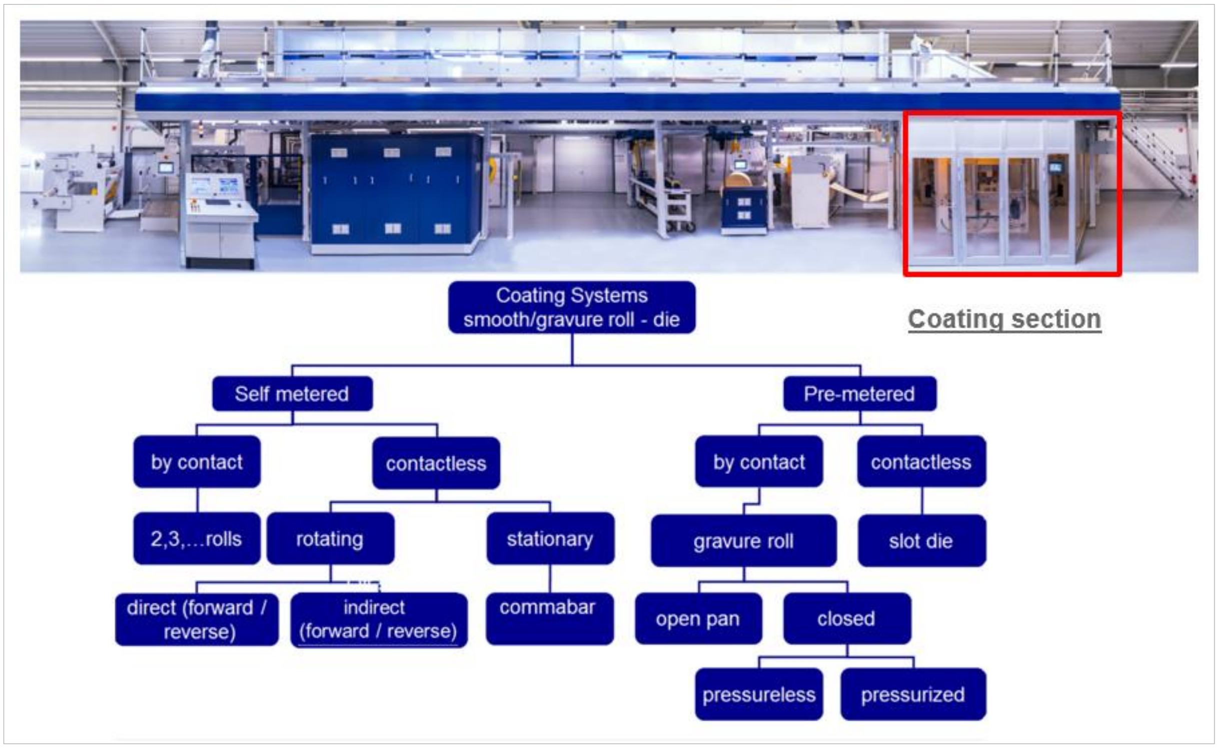


There are four Key Processes or Disciplines, which are critical to master, combine and balance in order to coat precisely and reliably. These are Coating, Drying, Winding, and Drives & Control Technology. Together with supporting processes such as web cleaning, process measurements (LEL etc.), surface pre-treatment (e.g. corona) and product measurements, these lead to customised processes.



As the development of coatings goes on, we need to test these for runnability and final product functionality. In order to do so, a pilot machine is required to explore these facets under near-production conditions.

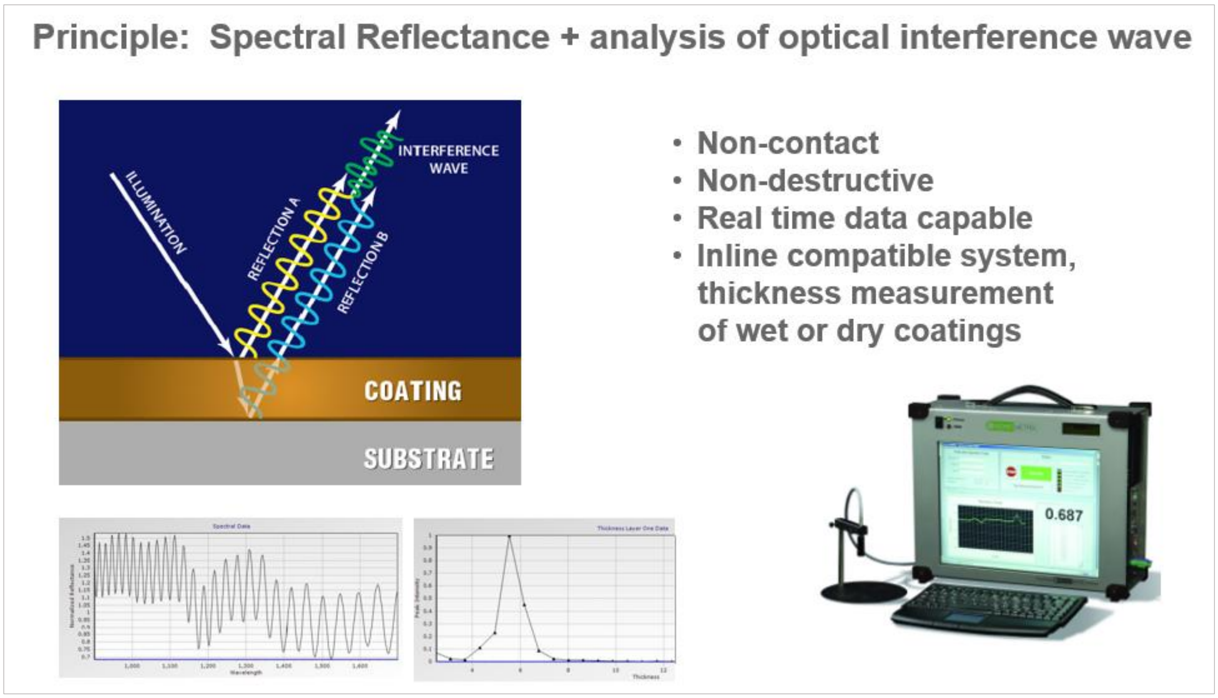
The machine used to test these conditions was a pilot coater with a working width of 1050 mm and a speed range of 2.5 – 500 m/min. At the front end, a single roll unwind system passes the web to a conditioner for normalising substrate conditions. After this, the option of web cleaning or corona treatment up to 16 kW is possible. The coating section houses a cartridge-type changeover system. Coating methods include, amongst others, roll coater, comma bar, gravure and dual layer slot die.



The drying section employs selectable combinations of proven nozzle technologies including air flotation and types which utilise the Venturi effect to control the web, with independent top and bottom air circulation. Suction rolls before and after the dryers isolate the web tension from the preceding coating section and subsequent laminating section, allowing fine control in the dryer. An optical measurement system after the dryer scans the web and delivers CD and MD substrate and coating thickness profiles simultaneously. Following the drying section, an unwind system and laminator prepare the web for rewinding with the turret rewinder, which is able to handle both thick (3.5 mm) and thin (15µ) materials and even woven fabrics sensitive to narrowing.

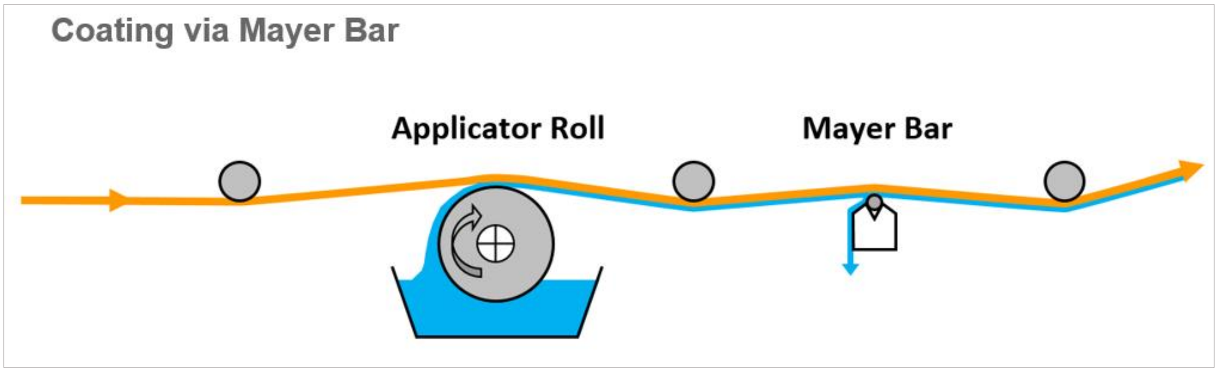
However, as good as our prerequisites may be for performing precision coating, we can never be exactly sure what we're doing until we measure the thickness in practice. We must have sharp instruments to gain deep insights into the coating thickness and its distribution. If we can't measure something, how can we improve it? We have to awaken our inner detective and be objective about interpreting results.

Our search for a thickness measurement system led us to a white light interferometer. The advantages of the system are that it is non-invasive, non-destructive and returns real-time data via fast inline measurement. Simultaneous measurement of coating and substrate is possible. It is a so-called “absolute” method, which requires virtually no calibration. This is due to the measurement principle, which uses algorithms to analyse the combined reflected light signal and calculate the path difference between reflected incident light and phase-changed reflected / refracted light from the layer boundaries. The only input required is the refractive index of the various layers. In addition, as the system uses white light, there is no danger from radioactive sources or X-rays.



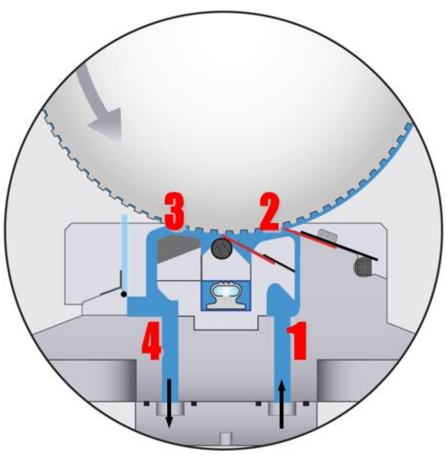
Case Study I – Protective Film Coating via Pressurised Doctor Chamber

Classically, protective films are coated using the Mayer bar. Using controlled web tension, the PE film or PE/PP blend is guided over an applicator roll to collect an excess of adhesive, which is then metered by the Mayer bar, essentially a wire-wound or grooved rod. The drawback of the technique is wrinkle formation due to the tension of the soft film. These form just before and after the Mayer bar and often lead to uncoated areas. When the coating fluid is highly viscous, it has to be diluted to become runnable, often resulting in fluids with only 10% solids content.



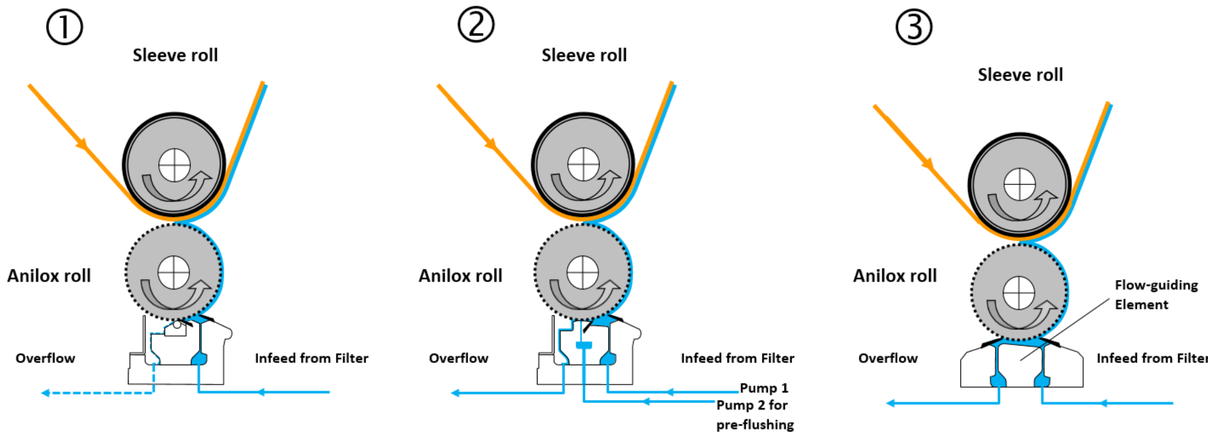
A pressurised gravure system, on the other hand, uses the chamber pressure to selectively overfill the engraved roll surface (or increase the speed at which complete filling is possible), expand the coat weight range and suppress foaming. In addition, this technology is superior concerning web handling, as the film is firmly held by the sleeve roll with a large wrap angle, and is coated in reverse mode, avoiding any wrinkles and depositing a superior coating compared to the stripy pattern from the grooved rod.

A classical pressurized gravure system can be split into 4 zones. In zone 1, the coating fluid is introduced to the chamber system and is distributed over the width. In zone 2, the pressure regulates the overfilling rate of the anilox roll surface in a controlled manner. In zone 3, pre-filling and air purging is performed, and any fluid with entrained air is removed from the system via zone 4.



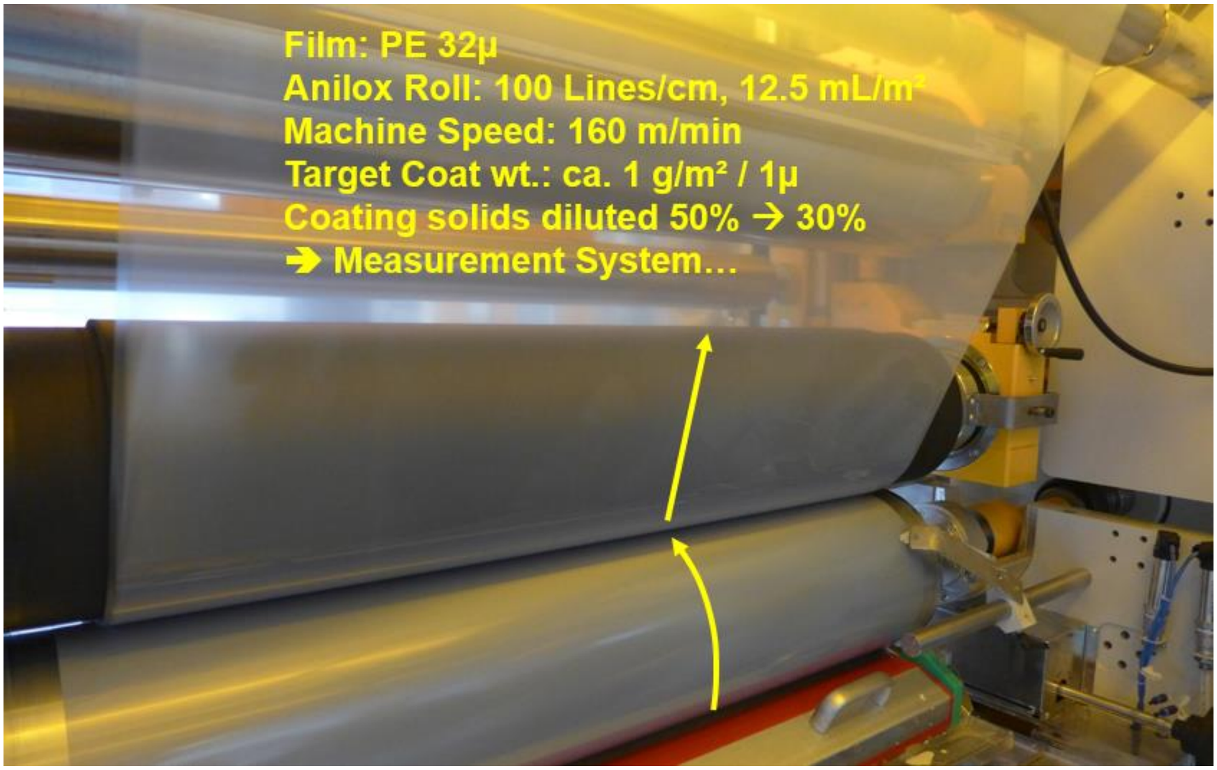
Although a pressurized gravure system ① can handle many coating tasks and has the advantage of low (or no) backflow, air exclusion becomes difficult at higher speeds and /or finer gravure required for low coat weights.

A modification ② incorporates a pre-flushing outlet on the roll incoming side. This 2-pump system enables independent control of flushing for air exclusion on the one hand, and chamber pressure for coat weight regulation on the other. However, at high speeds and when using very fine gravure (very low coat weights), deaeration is still not adequate.



A third variation ③ involves a so-called flow guiding element, which forms a wedge-shaped chamber to accelerate the fluid into the gap and deaerate the incoming roll surface. In addition, the chamber is longer than the other designs, which increases the deaeration time. The gap between the flow guiding element and the gravure roll can be adjusted to find a working window which suits both deaeration and overfilling rate. Experience shows that the finest engraving can be run at high speeds, necessitating only moderate dilution of the coating fluid.

In the practical example shown, 32µ PE film was coated with ~1 g/m² / 1µ dry adhesive. The anilox roll had 100 lines/cm and a surface volume of 12.5 mL/m². At 160 m/min, the coating appearance was excellent, and no hint of air entrainment was evident. Only moderate dilution of the coating dispersion from 50% → 30% was required.



The white light interferometer coat weight measuring system returned a pleasingly flat cross direction coat weight profile despite variations in substrate thickness.

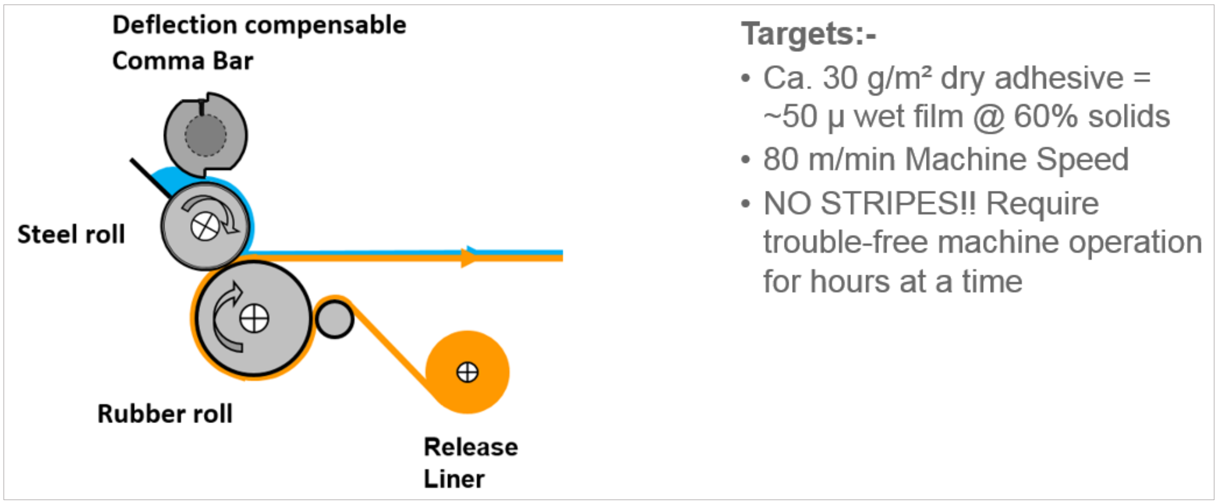
Varying the chamber pressure settings showed scope for coat weight adjustment in the range +20% → +55%.

Checklist Pressurised Chamber Gravure Coating

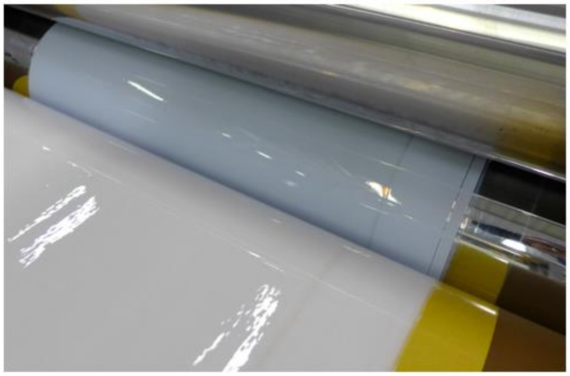
- ☑ Excellent runnability:-
  - ☑ No wrinkling as web is held flat on sleeve roll.
  - ☑ No air entrainment, complete filling of gravure at 160 m/min.
- ☑ Cross direction coating profile is even, despite variations in substrate thickness
- ☑ Ca. 1µ dry coating possible at 30% coating solids
- ☑ Varying the chamber pressure opens up a wide operating window in the range +20 → +55% coat weight

Case Study II – Novel Application Technique for Coating Shear-Sensitive Fluids

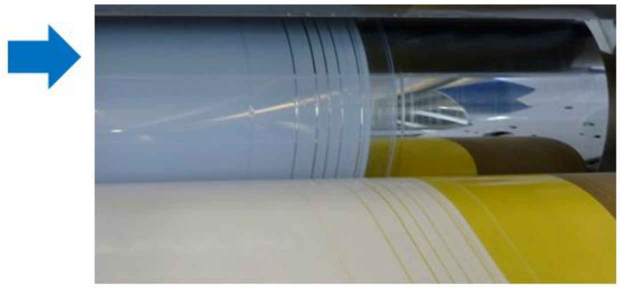
In the past, the solids content of aqueous adhesive dispersions was typically around 50%. Coating 30 g/m² dry with the comma bar corresponds to a 60 g/m² wet film, which can still be applied by setting the gap to ca. 60µm. However, adhesive developers have worked on increasing the solids of the adhesive to save drying costs and/or increase machine speed and improve the economics. To maintain 30 g/m², a solids level of 60% moves the required metering gap of the comma bar down to 50µm, which starts to become challenging. Along with the smaller gap and the resulting higher shear forces, the polymer particles are closer together. This proximity of the particles makes the elimination of water, the coagulation and the film forming easier. Suddenly, we are faced with a smaller gap, less favourable rheology and a higher tendency of the adhesive to prematurely coagulate and form disturbing particles.



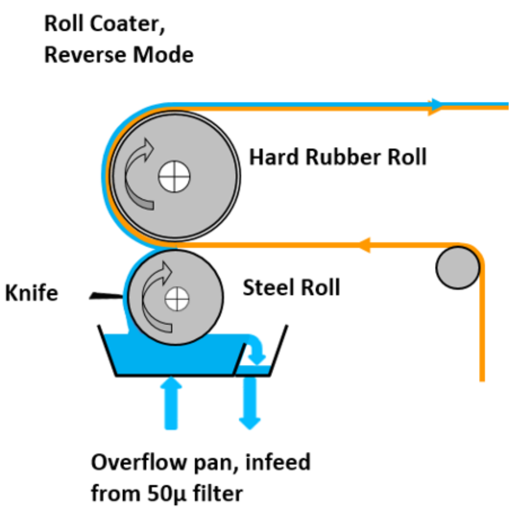
As the photos show, a classical comma bar /indirect setup employing Teflon side dams is prone to generating particles when coating a shear-sensitive adhesive dispersion, and this cannot be prevented by increasing the refreshment rate of the pond or by lubrication of the surfaces of the side dams touching the transfer roll. The problem compounds quickly, leading to stripes across the whole coating width.



- Particle generation between side dams and coating roll after just a few minutes of running.
- High refreshment rate of the pond only provides temporary alleviation.
- The particles migrate to cause stripes over the whole width.



A new concept designed to eliminate the side dams was devised, comprising a smooth transfer roll metered by a knife for accuracy in coating thickness.

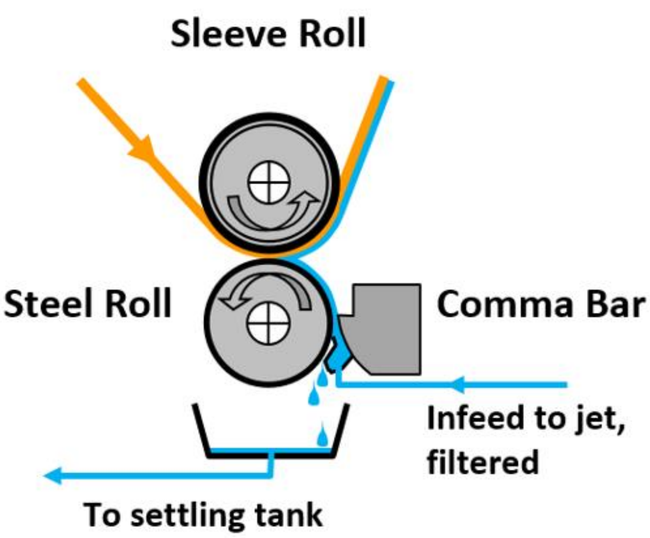


- Elimination of shear caused by side dams should prevent formation of particles
- Knife-over-roll is proven technology with good precision
- Overflow pan used with high refresh rate to remove any particles which may be present for whatever reason

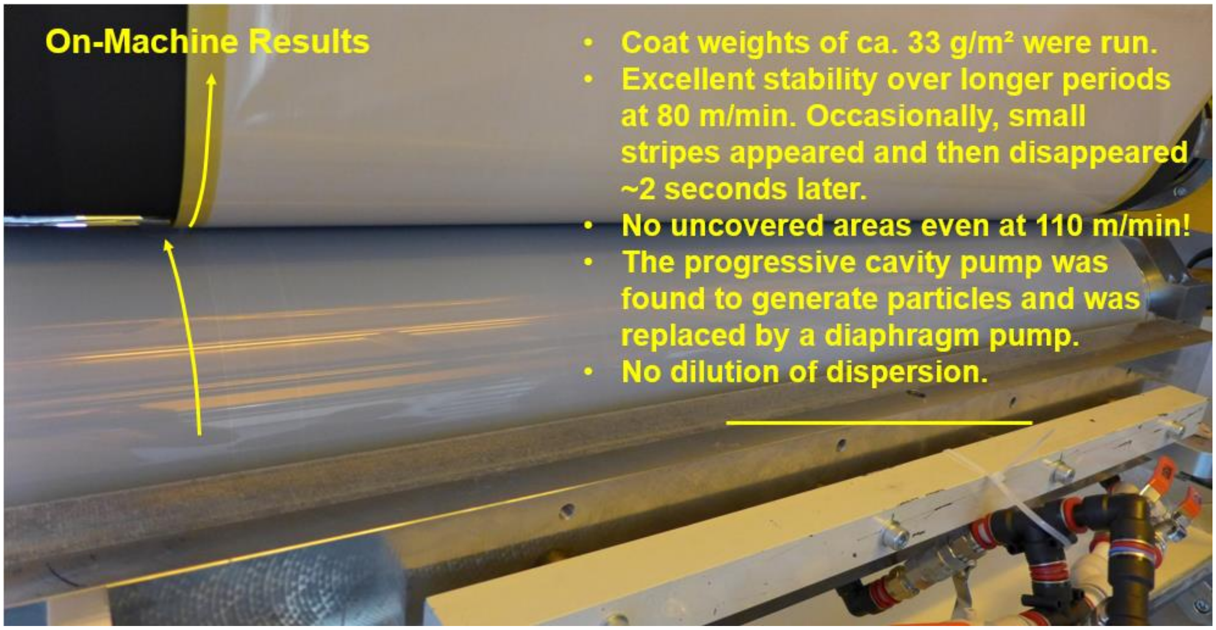
Putting the concept into practice returned good results: The coating appearance was excellent; moreover, long run times without particle generation were possible.

Unfortunately, transfer roll coverage was found to be patchy above 40 m/min. Baffles and guiding plates were not effective in bringing the dispersion reliably to the roll surface.

The idea arose to force-feed the roll surface with a kind of jet. This was designed and built to seal with the comma bar and have an adjustable gap to the transfer roll for optimising air exclusion and maintaining jet pressure (ca. 100 mbar).



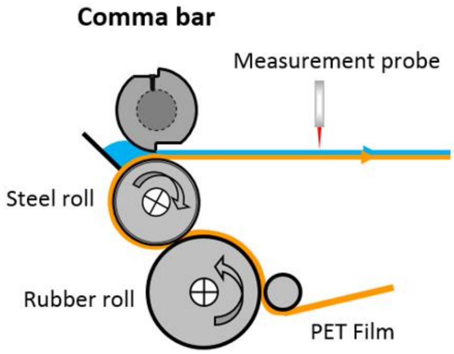
On-machine testing showed that the concept worked extremely well. Without any dilution of the adhesive, 33 g/m² dry coating was applied at 80 m/min for longer periods. No deficiencies in roll coverage were observed even at 110 m/min. Very small stripes appeared now and again, but were short-lived, disappearing after ca. 2 seconds. A diaphragm pump was used for adhesive supply, after a progressive cavity pump proved to be a source of particles.



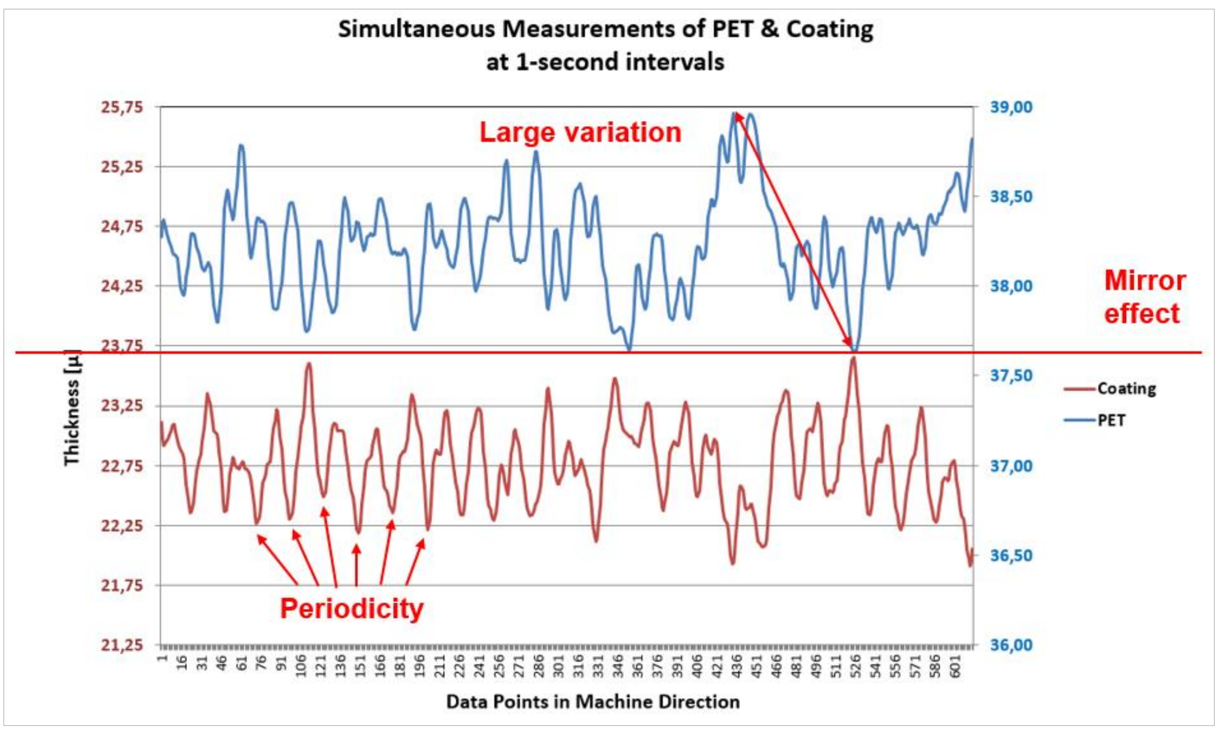
Summarising, the patience and tenacity to find a solution paid off. Elimination of high-shear hot spots was the key to success, enabling the targets for coat weight, stripes and speed to be met or even exceeded.

Case Study III – Use of White Light Interferometer to Qualify the Comma Bar Coating System

The comma bar coater is a popular coating technique, offering the precision and robustness of a high-tolerance roll at low complexity. However, no system is perfect, and there are still several points to consider when using it. The total runout tolerance of the backing roll, nip forces from viscous coating media and temperature all influence the overall result, and then there is the substrate with all its variations. To quantify the various sources of error, a white light interferometer is a handy tool and can help in ascertaining whether a system is process capable or not.



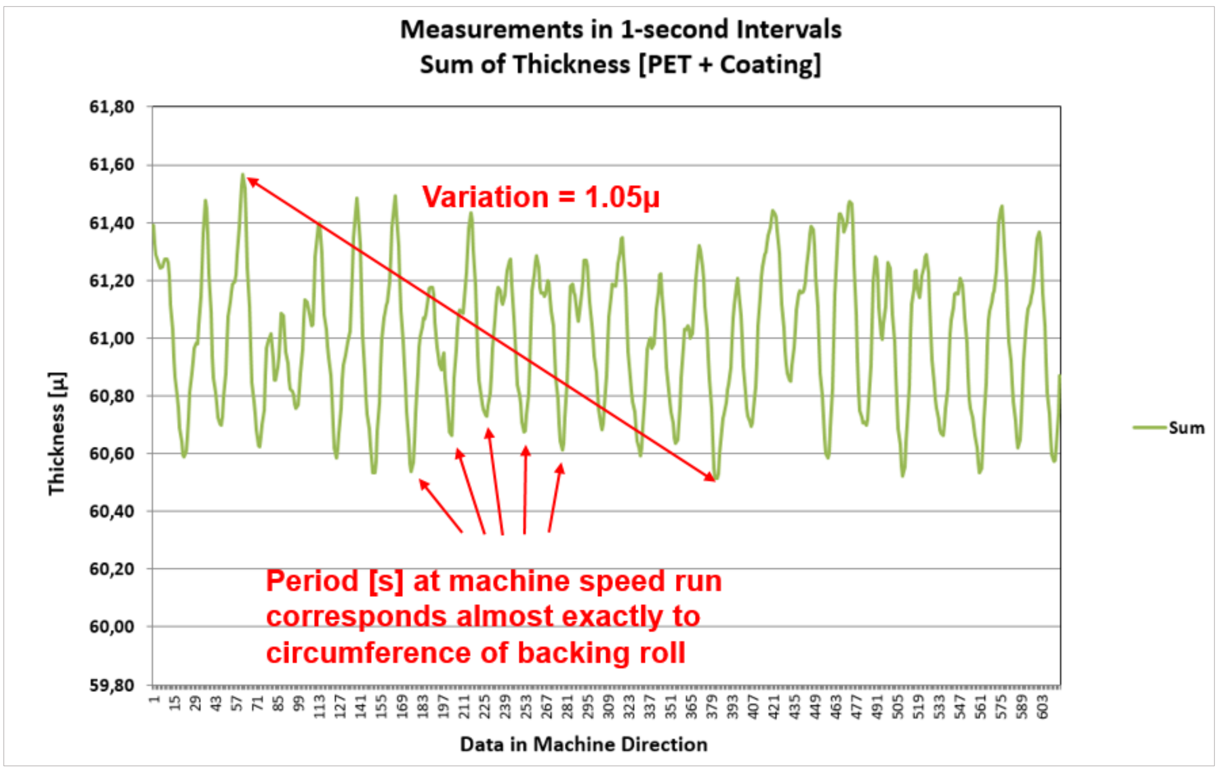
In the current example, 23 µm of a viscous fluid was applied to a 38 µm PET film. The white light interferometer allows us to measure both substrate and coating layer simultaneously. Exporting the data into a spreadsheet enables us to show the variations graphically and recognise trends at a glance.



As we would expect, when we are using a calibrated gap to coat, the coating layer becomes thicker when the substrate is thinner and vice versa. The graph shows a mirror-like behaviour, confirming the theory. Interesting to note is that the swing in PET thickness does not correspond to an equivalent swing in coating thickness – the latter is larger. This, and the presence of periodicity, suggest that other factors are in play.

- ✓ **Calibrated gap means that when the PET is thicker, the coating is thinner**
- **Variation in PET thickness 1.33μ (3.5% rel.)**
- **Variation in coating thickness 1.74μ (7.7% rel.)**
- **Difference shows that additional errors are present**

Adding the coating layer and PET thicknesses should return a constant value if we have a constant gap. The data are easily manipulated and present a surprising picture: Here we can see the fluctuation of the total thickness with astonishing regularity. As the comma bar is stationary, the variations can only come from the backing roll. Analysis of the periodicity at the speed run shows it to correspond almost exactly to the circumference of the backing roll. 1.05 µm total runout tolerance is an excellent value!



Summarising, we have quantified the sources of error in the coating system, and even measured the total runout tolerance of the backing roll! The total measurable swing in the coating thickness should theoretically be the error in the PET thickness + runout tolerance. This was not seen during the trial series as the “low” of the PET has to line up with the “low” of the backing roll. In the case study, the intrinsic error starts at 2.4 µm. Depending on the requirements, this may not be process capable, as the individual sources of error, even when apparently trivial, all add up.

- Addition shows that the variation in total thickness is 1.05µ
- Analysis shows that this is the total run-out of the backing roll. This is a low, excellent value for a manufacturing tolerance
- Variation in PET thickness 1.33µ (1)
- Variation due to run-out 1.05µ (2)
- Variation in coating thickness 1.74µ - why not higher?

➔ Must wait for alignment of 1+2 to see full swing in coat weight.

Conclusions:

- The potential coating variation of this system [Comma bar + PET] starts at ca. 2.4µ error. Ca. 55% of this error comes from the substrate in this case.
- Depending on the total coating thickness, the relative error may render the system to be non-process capable.

Concluding, we can say that modern instruments, when used prudently, help us create huge transparency of coating systems. Considering this knowledge when designing coating machinery will shape the developments of the future.

- Optical measurement systems enable us to perform detective work with coating systems and gain a deep understanding of:-
  - The coating process
  - Mechanical constraints
  - The Substrate quality
  - Variations in coat weight and coating distribution
- Feeding this knowledge back into the design stage of precision coating equipment shapes the next generation of products

❖ If you can't measure it, you can't improve it

In the quest to supply high performance coating machinery, it is clear that next generation equipment must provide full control of the precision coating process. Contributing factors include:-

1. Drawing on technology that creates transparency, giving us deep insights into coating operations, enabling us to recognise factors that influence quality.
2. "Know-why" – complex knowledge which inspires our judgment and choice of equipment when novel solutions are required, and
3. "Know-how" – engineering excellence, which brings ideas alive and delivers convincing technology.