Solventless multi-ply lamination: A review of process innovations and new technical developments

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Introduction

The most recent developments around the global energy crisis and the uncontrolled rise of its associated costs gave boost to a rethinking of the efficiency of industrial processes, in general, and processes relevant to the converting industry, in particular. Every conversion process goes through a significant use of energy. For those machines designed by original equipment manufacturers (OEMs) to be energy-efficient, the impact is limited. Nevertheless, there are technologies that, beyond being energy-efficient, definitely are energy-friendly.

Solventless lamination is an example. Introduced during the 1970s, it is a process that allows dramatic cuts in energy cost by completely eliminating the need for a drying oven and a process that this firm pioneered on the machinery side since its early days. Since then, the industry has adopted the technology to the point that solventless lamination constitutes more than 50% of the global volume of lamination and over 70% of new installations.

So, considering the current market, why doesn't such a technology cover the entire lamination industry? The reasons are quite well-defined. Among them are post-lamination process temperature limitations by solventless adhesives. Temperature performance of solventless-laminated pouches after product packaging is, in fact, improving as adhesive manufacturers develop new formulations, but still solvent-based adhesive lamination remains the proper technology to serve this particular market.

The state of multi-ply solvent-based lamination

There is a segment of adhesive lamination still dominated (in percentage of the market) by solvent-based adhesives: 3-ply lamination in one single pass. Constant demand growth for 3-ply structures has triggered a similar growth in installations of 3-ply single-pass laminators to improve productivity and quality while reducing scrap.

The key target market for 3-ply laminators always has been one of converters with significant 3-ply structure volumes. Machine configurations feature two coating stations, two drying systems, and turreted unwinds and rewind – an investment that becomes cost-efficient only as production volumes grow. This firm has served the industry with 3-ply single-pass laminators since the 1970s, pioneering the process. As such, our consistent database built during these past 50 years qualifies us to analyze industry trends and predict what realistically can be expected down the road.

While there are two main trends in the configuration of 3-ply laminators, the most appealing to the industry always has been solvent-based in a dry-bond setup. Such

FIGURE 1. *First 3-ply integral solventless laminator*

FIGURE 2. *Compact, triplex solventless laminator*

configuration allows for broad machine flexibility. Secondly, converters favor the solventless setup, in both integral and hybrid versions. Integral setup is configured exclusively for solventless adhesives, and hybrid is just that, configured with a first coating section using solvent-based, dry-bond adhesive and a second coating station using solventless adhesives. As the solventless setup may allow for less flexibility, it typically does represent a much lower capital investment and offers significant energy savings.

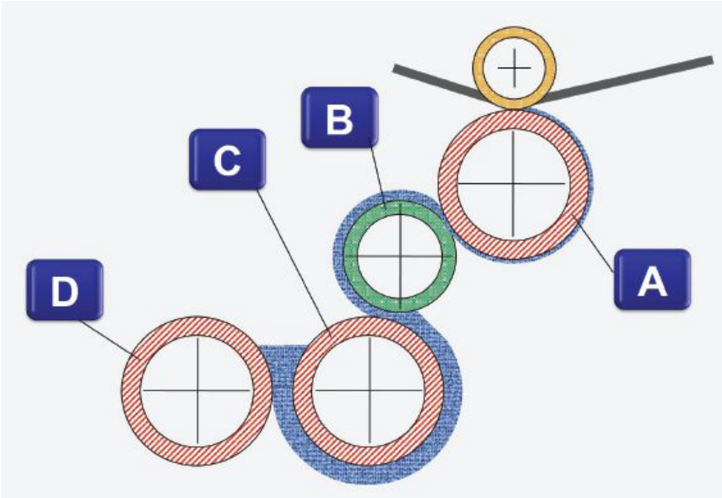

FIGURE 3. *5-roller coating-head design*

Review of solventless-laminator debuts

Important evolution in machine design for the integral solventless setup has been introduced since the 1990s, combining the know-how in 3-ply lamination with new concepts for solventless lamination. This first-ever 3-ply integral solventless laminator was introduced by this firm in 1994 (see Figure 1). Used mainly in Europe, it primarily was applied to coffee-packaging applications. The follow up came in 2010 with our triplex solventless laminator featuring a compact design and extremely short web path that provided significant scrap reduction (see Figure 2).

Motivated by energy savings offered by integral 3-ply solventless laminators, and fueled by the current energy crisis, industry attention to this machine setup currently is at a peak, widening the target market as energy costs rise globally. The final picture is one of an industry investing more in 3-ply lamination and, specifically, in integral 3-ply solventless processes as testified by an increased number of installations.

Background and cornerstones

This next section reviews some historical background and defines cornerstones developed over the many years of evolution in solventless lamination, in general, and multi-ply, solventless lamination, in particular.

The concept of solventless lamination was introduced in the 1960s by a couple of frontrunner adhesive manufacturers. The chemical part of the technology was set first, and several patents filed, but it was the actual conversion process to offer plenty of challenges.

- Issue #1: How to mix the two components, resin and hardener, that are at the base of the solventless-adhesive technology consistently and efficiently as required by an industrial process.
- Issue #2: How to handle the coating of a fluid at very high viscosity (a characteristic of early solventless adhesives) with an accurate calibration of coatweight and consistent stability at all process speeds and specifically during speed ramp-ups.
- Issue #3: How to manage web-handling of a compound made by two substrates with different mechanical properties, with a fluid coated between the two having the behavior of a lubricant more than that of an adhesive, due to the low bond at green offered by those formulations.

It was this firm that introduced and patented the solutions that, through today, are allowing the ease of use and,

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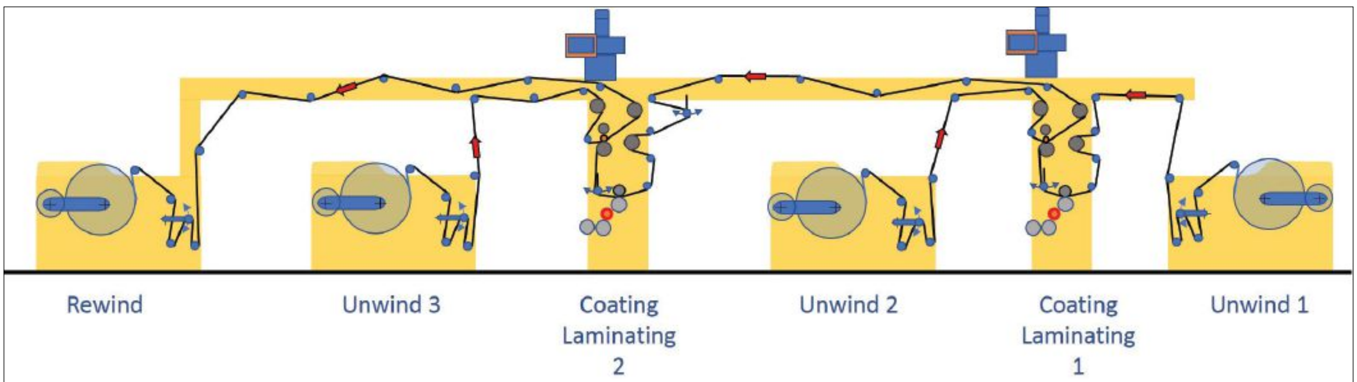

FIGURE 4. *Compact, triplex laminator web path with dual laminators*

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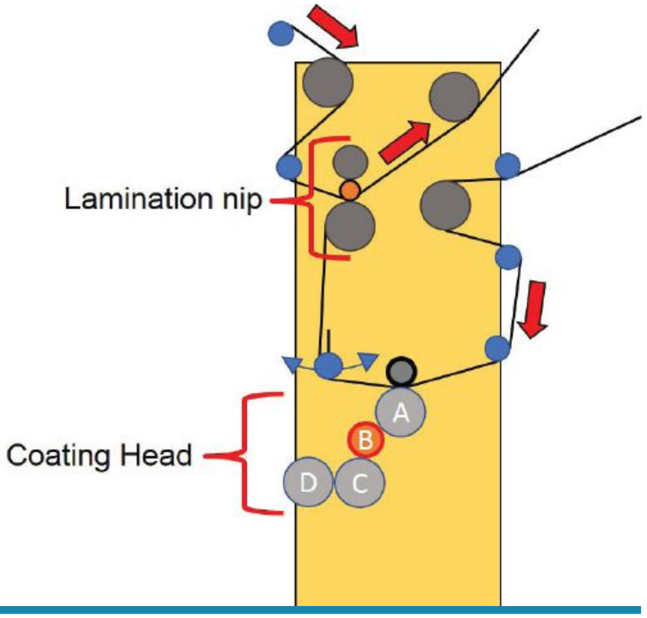

FIGURE 5. *Compact single-laminator web path*

consequently, the application growth of this technology. Figure 3 shows the patent-protected 5-roller system (the coating head design) that proved, in literally thousands of installations, to be accurate and consistent. making the process monitoring easy to learn and to run. At the base of the patent are the solid roller and the flotation technology of the rubber transfer roller, followed by the proprietary technology for web-handling, starting early with electro-mechanical solutions that evolved to unprecedented performance with digital solutions.

The development of a "compact laminator" concept next lead to a new machine-setup process that not only offered converters an accessible capital investment but a rapid return on that investment. This compact machine configuration opened adhesive-lamination technology to converters of any size. Also strategic was the development of an innovative meter/mixer/dispenser system, based on gear-pump technology, providing on-demand mixing and a reliable mixing-ratio performance.

In the thick of adhesive developments

While the annual number of installations was growing exponentially, adhesive manufacturers were busy perfecting the range of solventless adhesives available to cover as many converter needs as possible from commodity applications to high-performance ones. Basically, the early adhesives were characterized by *very high* viscosities requiring high process temperatures to reduce that viscosity to easier-to-handle levels. This required the relevant energy consumption and process-handling inconvenience at the coating head, but it also generated some help in web-handling because higher viscosities allowed for higher sheer resistance and, consequently, a more stable compound after the lamination nip (before polymerization and bond takes hold).

Considering the low accuracy of motor control (and consequently limitations in web-handling control) available at the time, high viscosities of the adhesives was not such a negative thing after all. The effect on the laminated compound was an improved stability (shear resistance grows with viscosity) for the lamination after the final nip and before the rewind.

The challenge of "multi-ply" solventless

So, why during the 1990s when 2-ply solventless lamination was experiencing constant process developments, resulting in easier setup and production monitoring was *integral 3-ply* solventless still such as challenge? I have witnessed multiple efforts at the R&D level to overcome those difficulties, working in parallel on the chemical side and on the hardware side. It was not until 1994 that the first solution was presented: our compact, triplex system (see Figure 1).

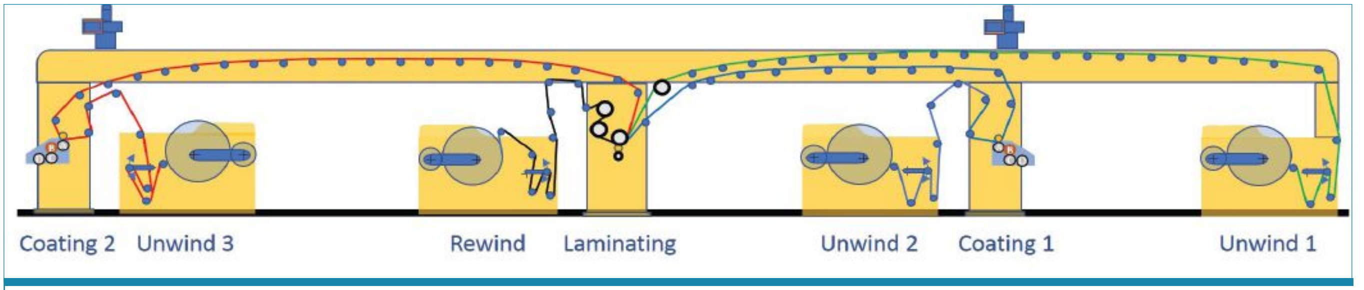

FIGURE 6. *Compact, triplex system web path with single laminator*

Figure 4 shows a simplified representation of the web path. From today's viewpoint, the concept seems pretty Old School: Coat adhesive on Web 1; laminate Web 1 to Web 2 at the first lamination nip; travel to second coating station and coat a second adhesive layer on the compound "Web1+Web 2;" then apply a third ply in a second lamination nip. The "compact" part of the name used for that machine setup referred to the close proximity of the coating head to the lamination nip, a very short webbing that was conceived to simplify web handling (keep in mind the low level of electronic controls at the time) (see Figure 5).

This compact arrangement triggered the need to handle the process at reduced speed because of CO2 entrapment generated by the gas released during solventless-adhesive polymerization. In almost all cases, 3-ply lamination involves use of barrier films, so CO2 released during polymerization remains trapped between the layers. (After all, being a barrier to gas is what barrier films are for.) A longer web path between the solventless-coating head and the lamination nip were identified later as the best solution to speed up the lamination process by allowing for consistent outgassing before the lamination nip.

From two laminator stations to one

By the late 1990s, a good number of that first-configuration, 3-ply solventless laminators was sold, primarily in Europe to converters involved in coffee packaging. A typical coffee-lamination structure was PET/aluminum foil/LDPE. It was the PET/foil that presented the side effect of CO2 entrapment and, consequently, influenced overall process speed. Converters' experience and process development provided setup recipes granting higher productivity and quality results. Solutions developed involved a smart adhesive approach with the use of high-performance (high shear resistance and high initial bond along with higher cost) adhesive on the PET/foil pass and a generic solventless formulation (lower performance *and* lower cost) for the second pass – the one involving the LDPE sealant. The solution offered both good performance and cost savings.

The compact, 3-ply setup remained the state-of-the-art for the next 12-13 years. Then, the configuration with two lamination nips became obsolete, influenced by growing technology application and innovation. In the early 2000s, the industry trended toward lower solventless-adhesive viscosities, demand for extended potlife and for higher process speeds with limited misting – all of which also helped solve web-handling issues. In 2008, this firm introduced its truly compact, triplex laminator with a single lamination nip (see web path in Figure 6). Since then, the machine has been released in multiple configurations to allow converters to benefit from not only a reliable, stable process but flexibility as well.

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FIGURE 7. *Recyclable, full-polyethylene barrier pouch printed flexographically*

Presented at drupa 2010, the machine was configured with two coating stations, only one lamination nip, and proprietary shaftless, single-position unwinds and rewind. The coating station location allows coating the two outer webs in the 3-ply structure with the additional benefit of overcoming any potential pinhole problems on the foil middle web. Alternative industries have used the system to incorporate as a middle web such materials as reinforced synthetic mesh, and its extremely short web path continues to minimize scrap for typically expensive webs. The patented setup has since won multiple innovation awards, including recognition as a finalist in the 2010 AIMCAL Technology of the Year competition.

Complex to mono-material structures

Today, industry attention is focused on recyclability and mono-material structures. Unprecedented results have been achieved in generating barrier through vacuum metallization in combination with high-performance barrier coatings. Such structures are under constant evolution as the industry awaits clear guidelines to be released by governing authorities. For those structures (MDO-PE, BO-PE and the like), it seems that the trend is toward polyolefin-based formulations. Handling such films through converting machines is critical because of their mechanical behavior. It is only intuitive that a machine setup with a short web path, low temperature stress and state-of-the-art web handling will allow successful, consistent lamination based on those substrates.

> “THIS [RECYCLED MONO-MATERIAL STRUCTURE] THUS OFFERS HIGH PERFORMANCE ON SEVERAL FRONTS AND COMPLETES A CIRCULAR-ECONOMY PROCESS.”

Specifically, this firm via a cooperative project with ExxonMobil, Henkel and a selected number of quality partners completed a new product development presented simultaneously at K 2022 in Germany and PACK EXPO International in Chicago. The finished, flexible mono-material pouch is a (96% polyethylene) high-barrier structure (see Figure 7). It is made with ExxonMobil performance (pPE) resin extruded on an Alpine 5-layer blown-film line with in-line Machine Direction Orientation (MDO). Two extremely thin functional layers have been applied to the film to boost barrier properties: a uniform and homogenous aluminum oxide layer (AlOx) applied via a Nordmet Plus 12F vacuum coater and a Henkel water-based barrier coating applied with this firm’s Super Combi 5000 system. Subsequently, film rolls either were flexographically or digitally printed and finally solventless-laminated on the Super Combi 5000 using Henkel custom solventless, recyclable adhesive.

Proven recyclability for circular economy

Figure 8 shows the sequence of layers in the above-described structure. The pouches, featuring impressive barrier properties to both oxygen and water vapor, have been passed onto converters for their own testing and evaluation. But the product development did not stop with the high barrier values achieved. Due to the 96% mono-material structure, pouches were sent to an Erema Group recycling plant in Austria, and the resulting resin has been made into secondary packaging (see Figure 9). This material thus offers high performance on several fronts and completes a circular-economy process. The plus for converters is the convenience to test on their own the actual packaging for consistency with property claims.

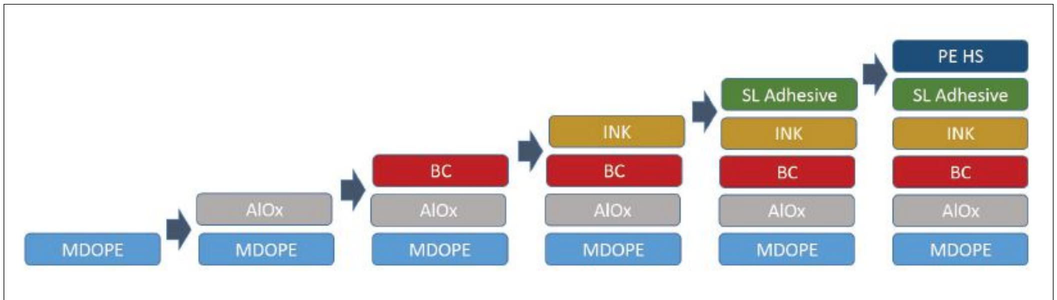

FIGURE 8. *Structure for recyclable, mono-material pouch*

FIGURE 9. *Secondary packaging made from recycled mono-material pouches*

All that said, we do acknowledge that the current global flexible-packaging market remains solidly around multilayer structures. There are several factors explaining why: costs; product shelf-life extension requirements; scarcity of certain innovative webs and processes; brand-owner preferences; and lack of clear regulatory guidelines, among others.

Conclusion

The adhesive-lamination process clearly is one of evolution. While 3-ply lamination makes up about 35% of global volume, the vast majority still is converted in back-to-back processes on 2-ply laminators. A growing number of converters today are equipped with 3-ply laminators, and those converters currently are serving the market with the quality and efficiency allowed by a single-pass process. A large share of the industry may even enjoy additional benefits (cost and process, sustainability-related) by resetting their 3-ply lamination to a solventless single-pass set-up and its 80% energy savings and zero VOC emissions. Market share is destined only to grow for solventless, multi-ply lamination as current higher energy costs are predicted to remain. ■

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