A Technology Decision – Adhesive Lamination or Extrusion Coating Lamination?

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Abstract

Extrusion-based coating/laminating and adhesive-based film laminating are different manufacturing techniques a converter can use to make a composite construction. The physical properties and performance characteristics of flexible packaging made by extrusion coating and laminating can be identical to that made by film laminating. Many of the major components of the final constructions are also the same. So which technique should be used for a particular product package? The decision is not an easy one, with equipment availability, run length, polymer specifications, and manufacturing efficiencies some of the major variables in this equation.

Introduction

The performance properties of extruded and adhesive-laminated structures are frequently dependent upon the types of polymeric, adhesive and surface treatment/priming ingredients combined to deliver the intended package performance. Multiple performance criteria such as mechanical properties, gas and moisture barrier properties, sealability, printability and cost will be integrated to satisfy the multiple performance properties of both rigid and flexible packages. Many polymeric materials are thermodynamically incompatible due to differences in their chemical make-up. Combining these materials can create the potential for phase separation and structural degradation. The key is to create a heterogeneous layering within an extrusion or adhesive lamination process so performance properties will not degrade over time.

Adhesive laminates can be made by dry bonding, wet bonding, UV/EB curing and by hot melt adhesion processes. Extrusion laminates are constructed by extruding a thin tie-layer of a plastic material to bond together two dissimilar materials, such as a polymer film, paper or foil. Furthermore, coextruded materials are produced by extruding several polymer layers simultaneously and then pressing/cooling them together. Incompatible layers are laminated together using a thermoplastic adhesive as a tie layer. Eight layers or greater can be produced to optimize barrier, material thickness, weight and cost performance parameters.

Surface modification techniques can also be employed to for low polarity polymeric films and other based substrates to improve structural performance. These methods can include the application of roll coatings (polymers, lacquers, primers), coextrusion, immersion, and plasma treatments. Solvent and water-based barrier coatings are common, as are dry coatings such as varnishes cured by heat or oxidation. Chemical surface treatments, vacuum plasma depositions, and specifically vapor-deposited oxides and nitrides are also employed to improve packaging performance.

Table 1 below details a comparison of mainstream lamination and coating processes. In the end, it

Advantages	Disadvantages
Hot Roll Lamination	
✓ Ability to apply a wide variety of films	✓ Medium speeds
✓ Low capital costs	✓ Printing distortions possible during lamination
✓ Low energy consumption	
✓ Ability to apply thin skins	
✓ Superior graphics	
✓ Simple technology	
Extrusion Coating	
✓ Inexpensive raw material	✓ Poor gauge control
✓ Improves structure stability	✓ High capital costs
✓ Ability to apply thin skins	✓ Little flexibility in coating type
	✓ High energy consumption
Adhesive Lamination	
✓ High speeds	✓ High capital costs
✓ Ability to apply a wide variety of films	✓ Medium energy consumption

✓ Ability to apply thin skins	✓ Requires adhesive to bond films
✓ Excellent print registration	

Table 1 – Comparison of Lamination and Coating Systems

is consumer demand for package features such as easy open packages, barrier properties, safety, tamper resistance, product efficacy, cost and manufacturing efficiencies which will directly determine which process will serve these interests. Fortunately, advances in resin technology, new chemistry options for coatings, and improvements in surface modification and sealing methods will enable new, high performance structures to better meet these challenges.

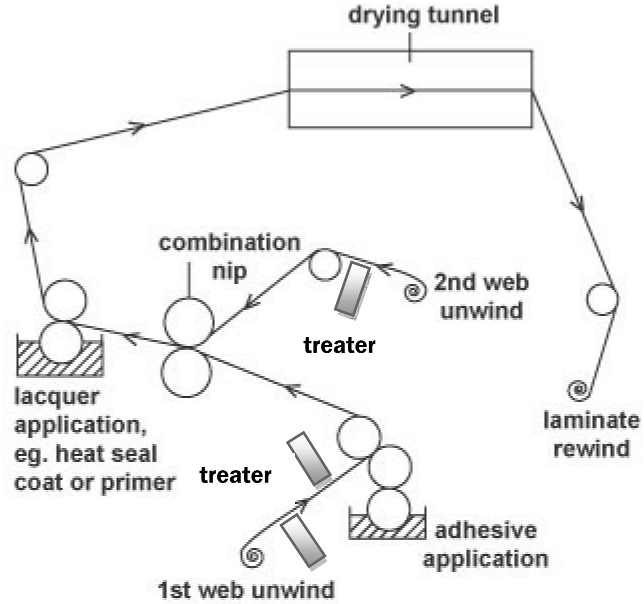
Adhesive Lamination – Wet & Dry Processes

The manufacture of film laminates is a continuous process of coating and bonding, with process differentiation defined by the type of adhesive used and how the adhesive is applied and converted. These processes are classified as either wet or dry laminating processes and are described in Table 2.

	Process	Description	Application Equipment	Typical Adhesives
Dry Processes	**Dry Bond Laminating**	Liquid adhesive coated on substrate, dried with heat/air flow, and laminated to a second substrate via heated compression nip.	Gravure application cylinder	Polyurethane dispersions, acrylic, emulsions, acrylic solvent, water-based polyvinyl alcohol, ethylene vinyl acetate copolymers, high solids silicone solvent
	Hot Melt Seal Coating	Low viscosity hot melt adhesives are applied to substrate	Heated rotogravure cylinder, extruder	Ethylene vinyl acetate, modified polyolefins, polyesters
	Cold Seal	Liquid adhesive applied, dried with heat/air, and bonded with slight pressure so tack to non-cold seal surfaces is minimized	Gravure application cylinder	Synthetic rubber, acrylic / natural rubber
Wet Processes	**Wet Bond Laminating**	Liquid adhesive applied to substrate, then immediately laminated to a second substrate via nip, followed by drying with heat/air flow (one substrate must be porous to allow evaporation of water or solvent)	Gravure cylinder or smooth roll	Polyurethane dispersions, acrylic, emulsions, water-based polyvinyl alcohol, ethylene vinyl acetate copolymers, polyesters, starch, dextrin, latex, etc.
	Solventless Laminating	Adhesive is metered onto substrata in liquid form, then mated to a second substrate via heated nip	Multiple application roll configurations	Polyurethanes (on- or two-component, with ester or ketone solvent, or 100% solids), polyesters

Table 2 – Adhesive Lamination Processes

Wet Lamination



Dry Lamination

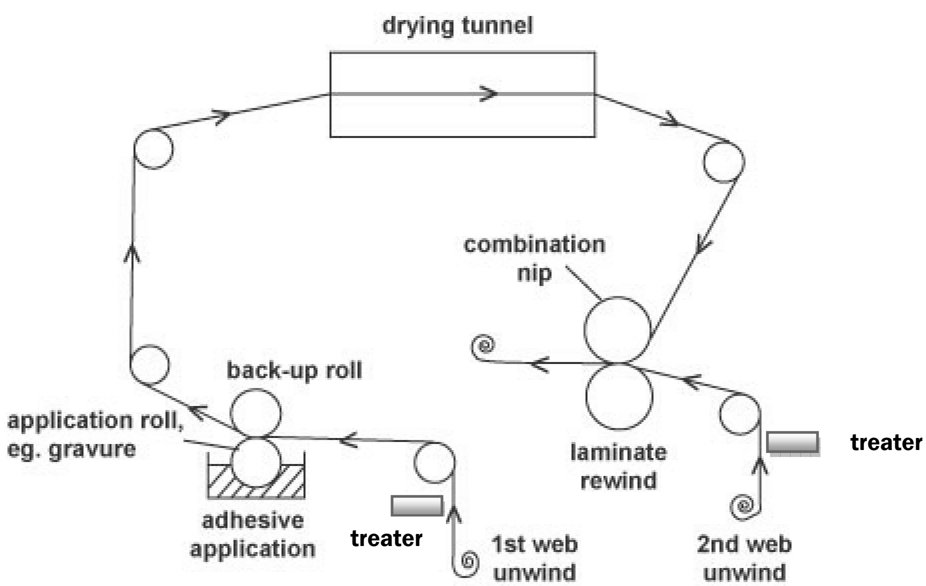


Figure 1. Typical Wet and Dry Lamination Process Configurations

There are a variety of process applications which dictate the level of adhesive coating thickness immediately following surface pretreatment by either a corona, flame or plasma discharge. Table 3 shows a summary of some of the capabilities and limitations of common adhesive coating methods that are used in producing laminates. For example, gravure-based adhesive coating has a required viscosity of 15-1500 cps for delivering a solution or emulsion – based coating weight range of 2-50 gm/m^2 at a coating speed between 100-700 mpm. UV or E-beam technologies, and chemical crosslinking agents formulated within the adhesive, are then introduced to the surface

Coating Method	Viscosity (cps)	Coating Weight (gm/m2)	Coating Accuracy (+/-%)	Coating Speed (mpm)	Adhesives Commonly used
Wire Rod	**100-1,000**	**15-1,000**	**10**	**100-200**	**Solution, emulsion**
Knife over Roll	**4,000-50,000**	**25-750**	**10**	**100-150**	**Solution, emulsion, 100% solids**
Reverse Roll	**300-50,000**	**25-250**	**5**	**100-400**	**Solution, emulsion**
Gravure	**15-1500**	**2-50**	**2**	**100-700**	**Solution, emulsion**
Extrusion Die	**400-500,000**	**15-750**	**5**	**300-700**	**Emulsion, hot-melt, 100% solids**
Slot Die	**400-200,000**	**20-700**	**2**	**100-300**	**Emulsion, hot-melt, 100% solids**
Curtain	**50,000-125,000**	**20-500**	**2**	**100-500**	**Emulsion, hot-melt**

Table 3. Adhesive Coating Method Parameters[1]

to initiate immediate tack and bond strength. Adhesive lamination is a preferred method of joining substrates when a film cannot by effectively processed through a coextrusion process because of equipment limitations, because of the potential for thermal damage by coextrusion, or when the use of adhesives will benefit the final construction. Therefore, it is primarily the physical and chemical properties of the substrate which will determine the type of adhesive and coating method which can be applied (sensitivities to water or solvent carrier, or to thermal drying), or whether adhesive lamination as a process can indeed be utilized.

Another key process variable is surface preparation along with adhesive selection. To ensure that adhesive will effectively wet-out and bond to the substrate, the adhesive must have a surface tension that is approximately 10mN/m lower than the surface tension of the substrate being coated. Typical pretreatment processes include corona and flame discharge, with high-density atmospheric plasma becoming an increasingly integrated surface treatment technology that is ideally suited for continuous polymer film lamination because of its introduction of chemical functionality for improved bond performance.

Solventless Lamination

Solventless laminating is the process of metering a low viscosity adhesive onto a multiple application roll configuration that applies the adhesive to a first substrate, which is then mated to a second substrate via a heated nip. Single component first generation adhesives were primarily moisture-cured polyurethanes. This adhesive is coated onto a substrate and atmospheric moisture reacts with excess isocyanate groups to crosslink the adhesive after it interfaces with the secondary film. Two-part solventless polyurethanes eliminate disadvantages of variations in ambient air moisture content, such as surface bubbling, variability in cure rate, and cloudiness, although pot life is limited. There are also high residual monomers and low initial bond strengths with two-part solventless polyurethanes. Late generation high performance aliphatic isocyanate-based solventless adhesives offer enhanced processing characteristics at reduced temperatures since the polymeric polyol have viscosities less than about 12,000 mPa·s at 25° C improve the meter-mix process, through enhanced flow rates, without the addition of heat.

Although a majority of printing today is done with solvent-based inks, environmental concerns have increased the demand for alternatives to solvent. It has been generally assumed that solventless adhesives cannot be used with water-based inks. While not every solventless adhesive works on every water-based adhesive, experiments have demonstrated that water-based inks yield bond strength and appearance that meet or exceed industry requirements when combined with solventless adhesives. Solventless adhesives are constrained, however, in their use with retort packaging by the lower coating weights provided by the solventless laminating process, typically in the range of 2.4 g/m2.

Hot Melt Laminating Adhesives

Hot melt adhesives in the laminating process span the base composition range of polyester, polyamide, EVA, polyethylene, and thermoplastic and reactive urethane. These adhesives are typically applied at ambient temperature to a substrate and activated using heat. A second web substrate is laminated to the first after the material is activated. Hot melt adhesives can also be applied directly and therefore more efficiently to the substrate via rotogravure, spray, or extrusion coating technology. Significant material savings can result by direct application of the hot melt adhesive, thus eliminating the cost associated with cryogenically created powders or formed films and webs. Also, ovens used to activate dry adhesives are not required in most cases, saving utilities costs and floor space.

UV/EB Curable Laminating Adhesives

Ultraviolet light (UV) or electron beam (EB) curing laminating adhesives are composed of acrylate / methacrylate monomers and oligomers. Aliphatic urethane acrylates are commonly used in laminations since they have good adhesion to most films, do not yellow, and have a very low application viscosity (350-450 cps.). In general, UV/EB laminating adhesives are directly coated on the surface of a film, nipped and cured at line speeds which can be adjusted by substituting UV lamps of different intensity. The process is generally based on free radical curing of acrylates. Cationic curing is also used, but in all cases at least one web must be a clear film when using a UV-based system. A process exception is the use of UV pressure sensitive laminating adhesives which hmay be used with opaque substrates, but which require higher adhesive weights compared to UV/EB laminating adhesives. Disadvantages of these pressure sensitive adhesives includes slower cure time due to lower functionality and oxygen inhibition, and lower chemical and heat resistance.

Extrusion Coating/Lamination

In extrusion coating and lamination, resin is melted and formed into thin hot film, which is coated onto a conveyed, flat substrate such as paper, paperboard, metal foil, or plastic film. The coated substrate then passes between a set of counter-rotating rolls, which press the coating onto the substrate to ensure complete contact and adhesion (Figure 2).

Extrusion laminating applies an extrusion coated layer which is used as an adhesive layer between two or more substrates. A second layer is applied to the extrusion coating while it is still hot and then pressed together by pressure rolls. The extrusion coated layer can also serve as a moisture barrier.

Substrates typically coated with polyolefins include paper, paperboard, BOPP, BON, PET and other plastic films, metal foils, fabrics, metal sheets and foams.

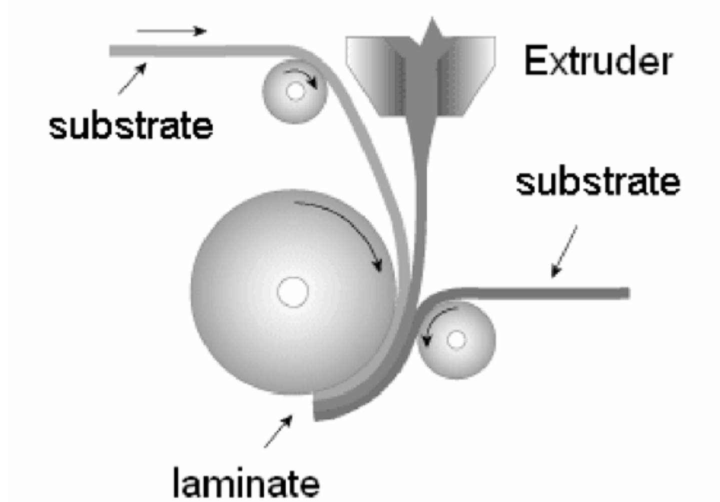


Figure 2. Extrusion Lamination Process

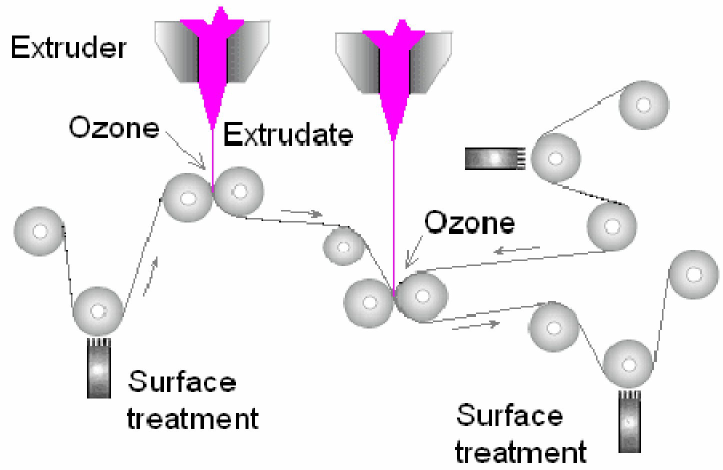


Figure 3. Coextrusion line and the location of ozone and surface treatment stations

Examples of common composite films are the materials for beverage pouchstocks and composites for the medical packaging industry. For example, the typical beverage pouchstock is a combination paper/PE/foil/PE, and composites used for medical packaging usually consists of PET/PE/foil/PE. These particular constructions involve four substrates and three interfaces which can utilize adhesives or primers at the interfaces. Converters can laminate the four substrates by means of three separate operations, or the layers can be combined together in extrusion laminations. The polyethylene layer can be composited in the construction by means of a coating extrusion from PE pellets, or with a lamination of PE film.

A major factor influencing extrusion bonds is the specific adhesion that is created by the capacity of the molten polymer to conform to, or match, the chemical composition of the substrate. In the examples mentioned above, and particularly the composite polyester/PE/foil/PE used for the medical packaging industry, the actual construction may be a polyester / interface / PE/foil/PE. At the polyester-polyethylene interface, a primer, adhesive and/or a surface modifier are necessary so that the polyester will adhere properly to the PE. Likewise, a pretreatment between the foil and PE is necessary to form a sufficient bond between those two substrates. It should also be noted that when chemical primers are used to improve extrudate adhesion, it is typical that a corona treater is required to pretreat film prior to priming and subsequent extrusion. Application of surface modification techniques to a substrate before an extrusion coating or extrusion laminating operation requires combinations of corona, flame, ozone and atmospheric plasma equipment to optimize adhesion (Figure 3 identifies a combination of ozone and other surface treatments). In some instances a chemical primer or an adhesive layer is used to improve lamination. Previous work which details the role of primers in extrusion lamination has been outlined by many, including industry professionals such as David Bentley in his paper on primers.

Extrusion bonding is also positively influenced factors such as melt quality, drawability, low neck-in and low power consumption. by high drawing rates for the extrudate. Regarding drawability, typically a short drawing time of between 0.1 to 0.5 seconds will lead to strong molecular orientation. The subsequent chemical structure requirements of the extrudate for easier processability involve control of rheological behavior, its reactivity in a molten state, its crystallization behavior, and its mechanical properties of E modulus and yield stress. The use of ethylene-acrylic ester-maleic anhydride terpolymers (polyvalent adhesives) are used to adhesion for LDPE by increasing reactivity in the polymer chain, and particularly with surface hydroxyl groups, amine groups, and atmospheric plasma-induced species. The more difficult the substrate (regarding adhesion) such as untreated films, OPET, OPP, CPP, OPA and printed surfaces, the higher the con-monomer content within a terpolymer recommended.[3]

Which Technique to Use?

The selection of whether adhesive lamination or extrusion lamination methods are used depends to a large extent upon the equipment available to a converter. Extrusion lines require extended runs to cost-justify the time required for process variables to reach a steady state of operation, whereas adhesive lamination lines are conducive for small quantity runs. Economical use of an extrusion line requires lengthy runs. Extrusion lines can offer a converter the opportunity to utilize a wide variety of polymers, particularly polyethylene-based resins and copolymers, whereas film users can be restricted by the range of available supplier films.

If the converter has the opportunity to design and purchase a new line to use either extrusion or adhesive laminating processes, capital costs are a key consideration. The expenditures can actually be equal if considering a complex adhesive lamination line relative to a simple extrusion line. In this context of investment, the number of processes a converter requires can be a deciding factor. The adhesive lamination of many base substrates may require a greater capital and space investment than extrusion (and particularly low thickness, 3+ polymer coextrusion) lamination.

Considering the performance of adhesive vs. extrusion lamination, a key metric is barrier. When looking to achieve barrier properties by use of adhesive vs. extrusion laminated inorganic barrier structures, the creation of oxygen barrier is dependent upon the lamination structures employed. As seen in Figure 4, significant enhancements in O_2 barrier can be designed into a lamination process.

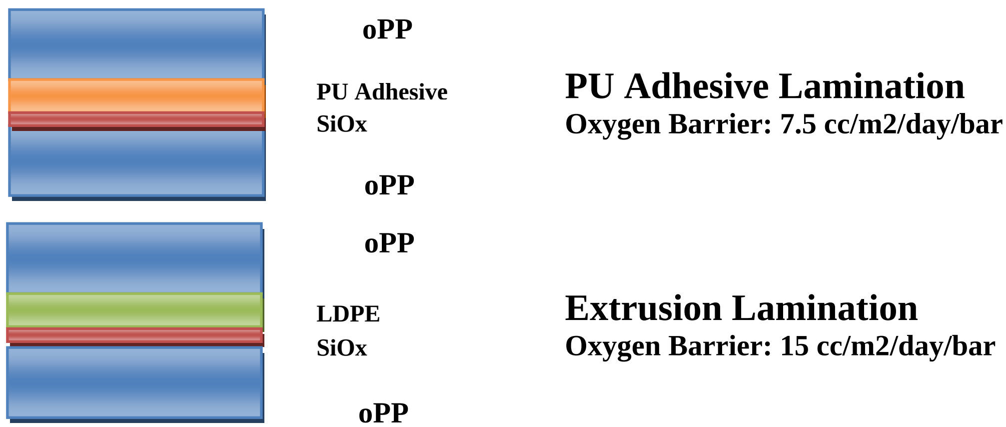


Figure 4. Example of Possible Clear High Oxygen Barriers Using Adhesive vs. Extrusion Laminated Inorganic Structures[2]

The choice of which process to employ is ultimately a complex one, but which may be best decided by the return on assets invested relative to the core competencies of the converter and the strategic market opportunities which will enhance this return.

References

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