Thermal Lamination of Ink Jet Photo Papers

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Abstract

Many commercially available ink jet media have excellent print qualities, but are difficult to laminate. Generally, unprinted areas have better adhesion to laminating films than printed areas. The lamination of secondary colors is often more difficult than primary colors. Images printed with pigmented inks are often much harder to laminate well than images printed with dye based inks. It is shown that, depending on the composition of the coating, unprinted areas can have lower adhesion than printed ones. The type of polyvinyl alcohol in the ink jet receiving layer could have significant influence on the adhesion of the laminating film. Partially hydrolyzed polyvinyl alcohol has better adhesion to unprinted areas than fully hydrolyzed. On the other hand, fully hydrolyzed polyvinyl alcohol provides better adhesion with primary and secondary colors. A mechanism to describe the migration of high boiling ink solvents and their influence on laminate adhesion is provided.

Introduction

Laminating of the printed image is employed in most of ink jet printing applications. At least eighty percent of ink jet prints are laminated.[1] Most media printed with dye-based inks are not water-resistant and have a tendency toward light fading. Laminating, especially encapsulating of prints, is necessary to protect against spillage, rain. Laminating also provides abrasion protection and allows the achievement of the desired gloss level and visual effects.[2,3]

Generally, there are two types of laminates: thermal and pressure-sensitive. Pressure-sensitive laminating films used in cold lamination are much more expensive than thermal laminating films. These types of laminating films are usually applied for mounting to boards and laminating specialty finishes. Thermal laminating films are more commonly employed in the wide-format ink jet industry due to the significant cost advantage. The hot laminating films are 4-5 times less expensive than cold laminating ones. However, its application to ink jet media is a great challenge because a few ink jet photo papers on the market can be laminated well by thermal film or hot lamination.

The bond strengths of a laminate depends on both the adhesive and the cohesive strength of the laminating system. Peel strength of the laminate is typically determined by debonding the laminate using a T-peel test.[4]

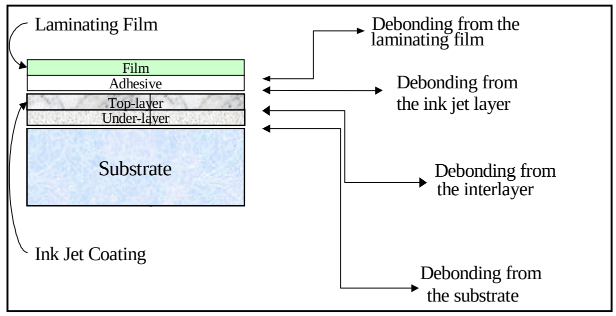

Figure1. Possible delaminating failures of ink jet laminated prints.

Figure 1 presents several possible modes of failure:
1) debonding of the ink jet underlayer from the substrate
2) debonding of the ink jet top layer from the underlayer,
3) debonding of the adhesive from the ink jet layer,
4) debonding the adhesive from the laminating film,
5) the substrate or film failure - tear.

The failure of the laminate will occur at its weakest link. It is generally common to have high bond strength to the substrate with failure occurring as the adhesive debonds from the ink jet layer.

Ink jet layers are usually made hydrophilic to absorb aqueous inks. The adhesives of laminating films are hydrophobic with some degree of polarity. The high bond strength of the laminate can be achieved if we understand the parameters governing adhesion of laminating film and ink jet layer. It is important to define the optimum matching of adhesives and the ink jet receiving layer in terms of compatibility. The compatibility of ink jet layers is dependent on many variables such as 1) polymers' composition of ink jet matrix, 2) the hydrophilicity of the matrix, 3) pigments, 4) surfactant system. In this study, the first two parameters are investigated.

Experimental

Materials

The 7-mil gauge polyethylene extrusion coated photobase was used as a base for model coatings. The base had a certain amount of polyethylene on the backside to compensate the possible curl after the ink jet coating application. The photobase was corona treated to achieve the surface tension about 42 dynes/cm before the ink jet receptive coating was applied.

Lamination

Lamination of all samples (three primary and three secondary color strips (1 inch × 10 inch) plus a non-printed strip (1 inch ×10 inch) was performed on commercially available laminators: MRL42 from USI or Falcon 36 from GBC Pro-Tech. The optimum lamination temperature was selected experimentally for each laminating film. Lamination was run at a rate of 0.48 meter/min.

Peel Strength Determination

TLMI Release and Adhesion Tester from Testing Machines Inc. was used to determine the peel strength of all specimens. The peel strength test was performed at a 180° angle and a rate of 12 inch/min (11). Average peel strength was reported in gram/2.54 cm. At least two specimens of each color from the same media were tested. The tester can detect the peel strength from minimum 0 to maximum 2000 g/2.54 cm. If the peel strength value is greater than 2000 g/2.54 cm, the specimen cannot be delaminated and coating layer failure occurs. The value of the peel strength greater than 2000 g/2.54 cm was simplified and taken as 2000 g/2.54 cm in the calculation of average peel strength for primary and secondary colors. For simplicity only, the adhesion values for primary and secondary colors were reported. The comparative laminate adhesion strengths of ink jet media were evaluated by this method.

It is essential that peel strength for secondary colors needs to be about 1000 g/2.54 cm to achieve long-lasting adhesion to the printed substrate. The adhesion to unprinted areas, which are on the edges of printed area, should be higher due to direct expose to delaminating forces. The peel strength should be above 1500 g/2.54 cm to have very good adhesion.

Results and Discussion

Lamination of Commercial Photo Papers

Four different commercially available photo papers were printed on an HP 2000 and an EnCad Nova Jet PRO printers with both dye and pigmented inks. They were subsequently laminated with 3-mil glossy film at optimum laminating conditions previously determined. Generally, it was found that better laminate adhesion was achieved at 20 °F more than manufacture suggested temperature.

The first photo paper has very good adhesion to most primary colors on both printers. The adhesion to secondary colors of HP dyes inks is marginal, about 680 g/2.54 cm. The laminating film debonds, on secondary colors (that is, zero peel strength) from EnCad dye inks and HP pigmented inks.

Three of the four photo papers tested have excellent adhesion to the laminating film in unprinted areas with peel strengths exceeding 2000 g/2.54 cm, as shown in Figure 2. The adhesion to secondary colors is lower than to primary for the first two photo papers. The ratio of peel strength between primary and secondary is in a broad range between 1 and 5. For HP pigmented inks, secondary colors have very poor adhesion to the laminate film.

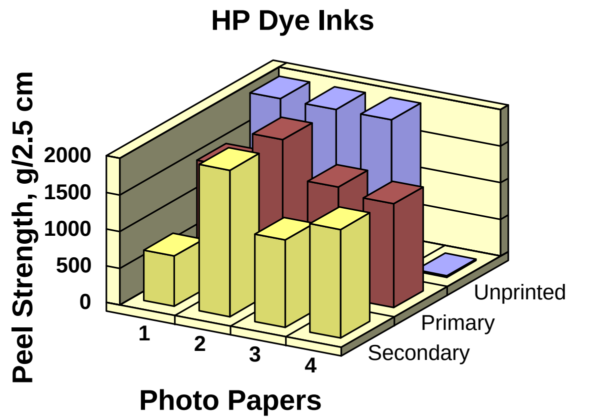

Figure 2. The comparison of adhesion properties measured as a peel strength for different commercial photo papers printed on HP 2000 printers dye inks and subsequently laminated.

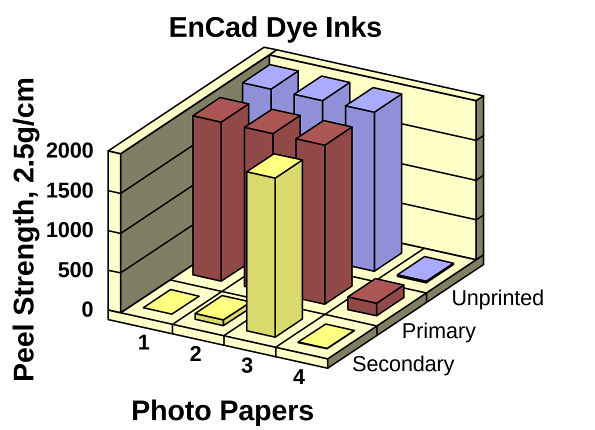

Figure 3. The comparison of adhesion properties measured as peel strength for different commercial photo papers printed on Nova Jet PRO printers dye inks and subsequently laminated.

The second photo paper shows excellent adhesion to HP dye inks, both primary and secondary, but poor adhesion to HP pigmented inks. This paper has also a very good adhesion to primary colors with EnCad dye inks but secondary colors can be easily delaminated.

The third photo paper has very good adhesion to both dye and pigmented inks on HP and EnCad dye inks.. It is worthy to mention that for this photo paper lamination adhesion to secondary colors is at the same level as to primary colors. This phenomenon also occurred in the second and fourth photo paper with HP dye inks

The fourth photo paper has unusual properties. This photo paper does not have any adhesion to the laminating film in unprinted areas. The printed areas have very good adhesion to the laminate on HP 2000 printer with dye inks. The adhesion is worse for HP pigmented inks and EnCad dye inks. It is assumed that the solvents presented in inks interact with the ink receiving layer softening its surface and making it more compatible with laminating film.

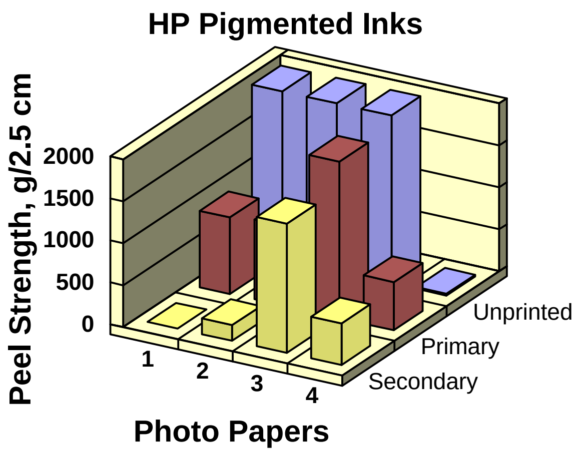

Figure 4. The comparison of adhesion properties measured as a peel strength for different commercial photo papers printed on HP 2000 with pigmented inks and subsequently laminated.

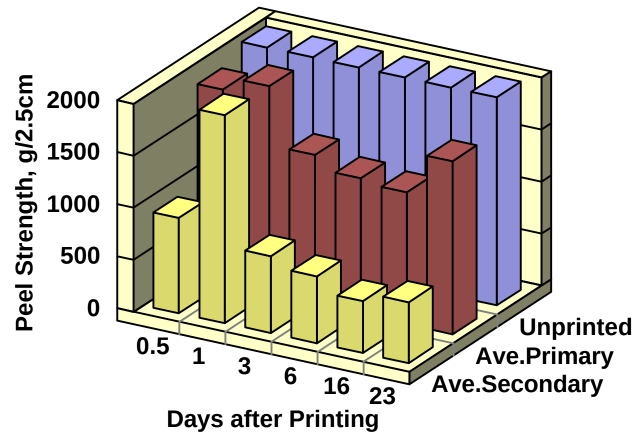

Figure 5. Peel strength of photo paper II as a function of the number of days after printing.

In general, each ink jet photo paper demonstrates a particular lamination characteristic with different inks. It essentially resulted from the chemistry and the design of the ink jet coating. In most cases, ink jet media can be laminated very well on an un-printed area. Lamination adhesion would be lowered to some extent once ink jet media were printed with inks. Ink jet media with dye inks demonstrate better lamination adhesion than with pigmented inks because the dye-based inks can more easily penetrate into the ink jet receiving layer than can pigmented inks.

Lamination Time after Printing

Most ink jet media printed in small shops are laminated immediately, despite the recommendation of manufacturers to wait at least 24 hours prior to laminating. The media providing good laminating properties immediately after printing will have competitive edge in the marketplace. The effect of time after printing prior to lamination on adhesion was studied for three different commercial photo papers having designation I, II and IV.

The strength of the lamination adhesion for photo paper I is independent of the period between printing and subsequent lamination. Peel strength of primary colors (1500 g/2.54 cm) is higher than secondary colors (700 g/2.54cm) and unchangeable in three weeks testing period. The lamination to unprinted areas is the highest and exceed 2000 g/2.54 cm.

Glossy photo paper II has excellent laminate adhesion to unprinted areas (Fig. 5). Once again the adhesion to primary colors is higher than to secondary colors. Peel strength of primary colors decreases from 1700 g/2.54 cm after 12 hours to 1300 g/2.54 cm after 6 days. After this period adhesion increases slightly. A much bigger difference is observed for secondary colors. Peel strength increases from 900 g/2.54 cm after 12 hours to 2000 g/2.54 cm next day and subsequently drops to 500 g/2.54 cm after 6 days. The peel strength numbers increase slightly with increasing time between printing and laminating but never approach the peel strength one day after printing.

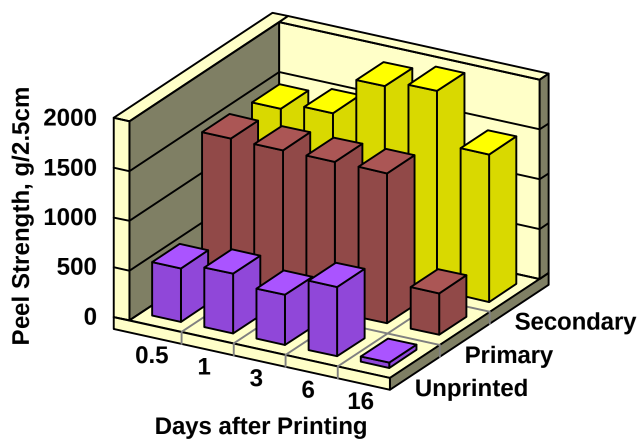

Figure 6. Peel strength of photo paper IV as a function of lamination time after printing.

There is a striking difference between photo paper IV and other tested grades (Fig. 6). This paper has limited adhesion to unprinted areas and peel strength decreases steadily with an increase in time between printing and lamination. After 16 days from printing, the paper does not have any adhesion to the laminating film. Adhesion of primary colors is lower than secondary (this phenomenon was explained in one of previous chapters). The peel strength of primary colors is at the same level of 1500 g/2.54 cm for about a week and decreases to 450 g/2.54 cm after 16 days. The peel strength of secondary colors increased from an initial value of 1500 g/2.54 cm to the maximum 2000 g/2.54 cm and subsequently drops to the initial value.

Lamination of Primary and Secondary Colors

Ink jet technology uses CMYK color systems consisting of three primary colors: cyan, magenta, yellow and black. Secondary colors: blue, green and red, are compositions of primary colors. A double amount of inks is deposited on the ink receiving surface for secondary colors.

This double amount of inks is not as completely absorbed into the ink receiving layer as is the case with primary colors. With secondary colors, more of the ink stays on the surface of the ink receiving layer.

Table 1. Peel strength (g/2.54 cm) of formulation I at coat weight 5 g/sq.m., printed on HP 2000 with dye inks and subsequently laminated.

Primary Colors	Peel Strength, g/2.5 cm	Secondary Colors	Peel Strength, g/2.5 cm
Black	1004		
Cyan	1035	Blue	689
Magenta	980	Green	519
Yellow	1107	Red	786
Average	1031	Average	665
Ratio	1.55		

Consequently, for most of tested ink jet papers laminate adhesion to primary colors is better than to secondary colors. Table 1 presents peel strength values of primary and secondary colors for the ink jet receiving layer, optimized for lamination purposes.

In the optimized ink receiving layer the laminate adhesion of all primary colors is nearly the same. For photo paper formulation at coat weight 5 g/sq.m peel strength is about 1000 g/2.54 cm. Peel strength of secondary colors is about 1.55 times lower than primary. The adhesion grows with coat weight and the difference between primary and secondary colors diminish as described in the next section.

Coat Weight Effect on Lamination

It is well known that print quality is strongly dependent on ink jet receiving layer coat weight, but the relationship is not straightforward. At high coat weight colors density becomes low and print defects such as banding is observed due to insufficient ink spread between two consecutive head passes

The effect of coat weight of the photo paper formulation coated on an impermeable substrate such as photo base on laminating properties of primary and secondary colors is presented in Fig. 7. It is seen that adhesion, expressed as peel strength, increases with coat weight. This relationship is slightly different for primary and secondary colors. Peel strength of primary colors reaches a plateau 1900 - 2000 g/2.54 cm at 8 grams per sq.m. For secondary colors adhesions increases constantly with coat weight and is at the level of 1700 g/2.54 cm at 20 grams per sq.m., still below the value for primary colors. For the typical ink jet coat weight in the range 8-12 grams per sq.m. the difference in peel strength between primary and secondary colors is double.

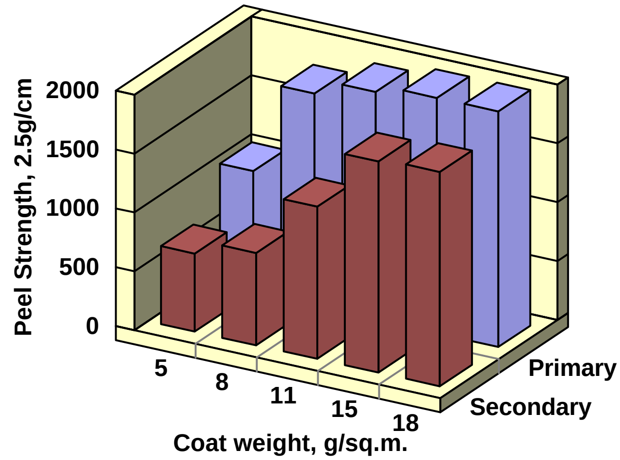

Figure 7. Peel strength as a function of ink receiving layer coat weight

It was shown in previous section that ink solvents causes a deterioration in laminate adhesion in most cases. With an increase in ink receiving layer coat weight, more ink penetrates deeper into the polymeric matrix and less stays on the surface. Since inks become entirely absorbed by the layer, the peel strength improves with coat weight. Several independent experiments carried out by the authors showed those coat weights above 12-16 grams per sq.m. are needed to provide sufficient laminate adhesion in areas printed with secondary colors. An increase in coat weight can allow lamination in a shorter period of time after printing, which can have a significant effect on small print office performance and profitability.

Laminating Characteristics of Polyvinyl Alcohol

Six different grades of polyvinyl alcohol (PVOH) commonly used in ink jet technology were coated on a paper with a polyethylene layer previously corona treated to define the parameters governing laminating properties. Polyvinyl alcohol Airvol 125 is fully hydrolyzed (above 99.3 percent), while Airvol 523S degree of hydrolysis is 87-89 percent. Cationic modified polyvinyl alcohol A and B have 99 and 88 percent degree hydrolysis, respectively. Anionic-modified polyvinyl alcohol C and D have 97 and 93 percent degree of hydrolysis. The sheets with different polyvinyl alcohol layers were printed on HP 2000 printers with dye and pigmented inks and subsequently laminated.

Figure 8 presents the adhesion results for different polyvinyl alcohols. It was found that the films of vinyl alcohol polymers printed with pigmented inks do not have any adhesion to the laminate and these data are eliminated for better clarity. Laminating film has excellent adhesion to unprinted areas for four tested polyvinyl alcohols that are above 2000 g/2.54 cm. The adhesion to unprinted areas is lower for fully hydrolyzed Airvol 125 and cationic modified highly hydrolyzed PVOH A (1443 and 1051 g/2.54 cm, respectively).

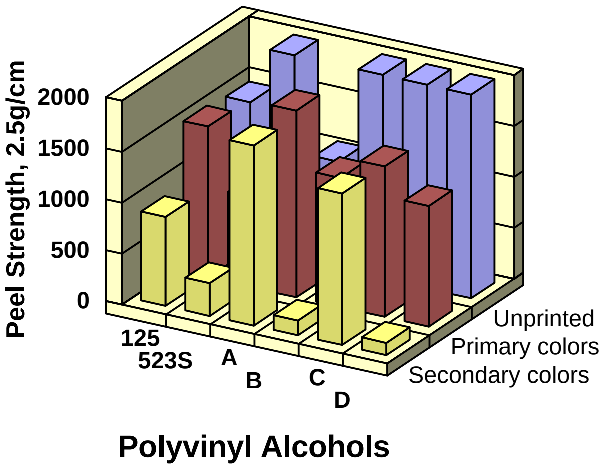

Figure 8. The comparison of laminate adhesion measured as a peel strength for different types of polyvinyl alcohol used in ink jet receiving layers printed on HP 2000 printer with dye inks.

It was found that the degree of polyvinyl alcohol hydrolysis has an effect on laminating properties for the dye inks. It is seen that a surface of polyvinyl alcohol with a high degree of hydrolysis provides higher peel strength for primary and secondary colors than the surface with a partly hydrolyzed PVOH. The difference is observed for both unmodified and modified partly hydrolyzed polyvinyl alcohol. For example fully hydrolyzed polyvinyl alcohol (Airvol 125) has a peel strength to primary and secondary colors of 1482 and 872 g/2.54 cm, respectively, while for unmodified Airvol 523S the peel strength is 882 and 317 g/2.54 cm, respectively. A similar striking difference is seen for cationic modified polyvinyl alcohol A and B (1829 versus 1266 and 1766 versus 144 g/2.54 cm, respectively).

The interaction between laminating adhesive and ink receiving layer is a very complex phenomenon. Ink receiving layer of fully hydrolyzed polyvinyl alcohol provides medium adhesion in unprinted areas but good in printed areas. Partly hydrolyzed PVOH has excellent adhesion in unprinted areas but much lower adhesion in printed areas, especially secondary colors. Most laminating films are based on ethylene vinylacetate copolymers and blends as an adhesive. Acetate groups of copolymer interact with acetate groups of partly hydrolyzed PVOH and provide adhesion. This explains good adhesion to unprinted areas for partly hydrolyzed polyvinyl alcohol. On the other hand, hydroxy groups from fully hydrolyzed polyvinyl alcohol do not have the same ability to interact with acetate groups, and therefore laminate adhesion to unprinted areas is significantly lower.

The interaction between laminating film and ink jet receiving layer can change dramatically after printing. Ink jet inks solvents such as glycols are probably incompatible with acetate groups because adhesion drops with decreasing in degree of PVOH hydrolysis. On the other hand, fully hydrolyzed PVOH improves adhesion due to interaction of hydroxy groups of polyvinyl alcohol with hydroxy groups of glycols. It apparently prevents polyvinyl alcohol crystallization and provides better laminate adhesion.

Conclusions

The paper discussed several factors influencing the design of ink jet media in respect to lamination. Four commercial photo papers were also printed with different inks and subsequently laminated. It was shown that laminating of ink jet photo papers can be done with limited success only. The lamination adhesion was studied for single layers of several grades of polyvinyl alcohols having different degree of hydrolysis to define the parameters governing laminating properties. The effect of coating weight of the ink jet receptive layer on thermal lamination was also investigated.

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Biography

Tom Graczyk received his Masters and Ph.D. in Polymers Chemistry and Technology from Technical University of Lodz. He worked for ten years in Pulp and Paper Research Institute in the area of polymers coating for specialty papers. Subsequently, he worked as a visiting scientist at several universities in Canada. He joined Oce Imaging Supplies in 1996 to work on media for digital printing with strong emphasis on ink jet media. Dr. Graczyk published over 50 technical papers in the area of polymers, pulp and paper, hot-melts and holds 6 patents.