Lamination Performance of Ink Jet Matte Papers

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Abstract

In media with non-porous substrates the ink receiving layer absorbs all inks. In porous substrates such as cellulosic, the substrate absorbs a significant amount of water and chemicals passing through the ink receiving layer. A difference in absorption between two types of media has an effect on interactions with lamination films. A dozen commercially available media were printed with several inks and laminated. It was found that laminating adhesion increases with the paper base weight. Peel strength is also dependent on type and characteristic of paper sheets. An interaction of inks with paper sizing agents can significantly reduce internal bond strength. The paper internal strength was frequently lower than the adhesion between laminating film and ink receiving layer and in the delamination test the paper was torn apart.

Introduction

Lamination 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 to UV fading. Lamination, especially encapsulating of prints, is necessary to protect against spillage, rain and UV light. Additionally, it also provides abrasion protection and allows achieving the desired gloss level and visual effects.[2-4]

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

Graczyk and Boping compared adhesion of five commercially available laminating films to four ink jet photo papers imaged with several dye and pigmented inks.[5,6] Generally, unprinted areas had better adhesion to laminating films than printed areas. The lamination of secondary colors was frequently more difficult than primary colors. Images printed with pigmented inks were often much harder to laminate than those with dye based inks. It was shown that depending on the composition of the coating, unprinted areas could have lower adhesion than printed ones. It was also found that the type of polyvinyl alcohol in the ink jet receiving layer could have significant influence on the adhesion of the laminating film.

These media were non-porous and ink jet receiving layer absorbed all the inks. In porous media such as cellulosic, paper can absorb significant amount of water and chemicals passing through ink jet receiving layer. It can change the degree and nature of interaction with lamination film. This paper presents the study of the influence of different raw paper bases and ink jet coating coat weights on lamination performance. Several commercially available ink jet coated matte papers are also imaged on different printers and their lamination properties are compared.

Experimental

Materials: Several papers 80-90 g/m^2 were used as a base for coating ink jet formulas. Surface sizing of these papers measured as HST was in the range of 120 - >5000 seconds at 85 percent reflectance and Sheffield smoothness was in the range 390-540 cc/min. A dozen of commercial ink jet paper bonds for wide format CAD and graphic art applications were imaged with heavy paper mode on different printers.

Laminating film: 3 mil thick, glossy film recommended in the previous study for lamination of wide format ink jet media was used in this paper.[6]

Formulations Preparation

Batches of about 250-g size were prepared for each formulation. The ingredients were added slowly one by one and blended using a high torque laboratory mixer with an RPM display. Most polymers were premixed with water to prevent any possible precipitation or coacervation. Water was used to adjust the final concentration and viscosity of the formulations. Subsequently, the blends were gently mixed by a magnetic bar to prevent any changes in the mixes. Viscosity of the coating formulations was measured at 60 RPM using Brookfield Synchro-Lectric Viscometer. In formula I the pigment to binder ratio was 4 to 1. In formula II the pigment to binder ratio was 1 to 1.

Prints for Lamination Test

An imaging pattern (21.59 cm × 27.94 cm) was used for testing the laminating properties of ink jet media. Three primary and three secondary color strips (2.54 cm × 21.59 cm) plus a non-printed strip (2.54 cm × 21.59 cm) were designed for determining peel strength of each color and non-printed area printed parallel to each other.

Lamination

Before lamination a strip of paper (2.54 cm × 27.95 cm) was placed vertically on the top of the printed test pattern to cover all the colors. This procedure allowed us to initiate the peel test later on. Lamination of all samples was performed 24 hours after printing on commercial laminator Falcon 36 from GBC Pro-Tech. The optimum lamination temperature was 20 °F higher than the film manufacturers' suggested temperature 220 °F. Lamination was run at the rate of 0.48 meter/min.

Peel Strength Determination

Eight 2.54 cm × 20.4 cm strips were cut from each laminating test sample by a specimen cutter. 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 30 cm/min (7). Average peel strength was reported in g/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. The peel strength value 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 simplistic reasons the average adhesion values for primary and secondary colors were reported. The comparative lamination adhesion strengths of ink jet media were evaluated by this method.

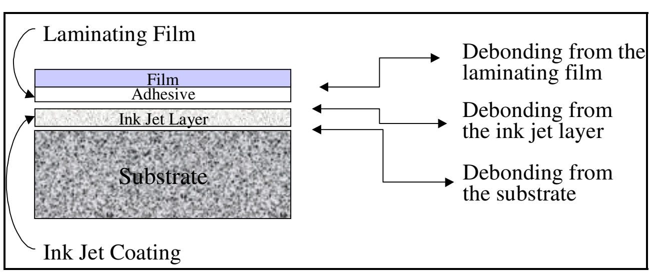


Figure 1. Possible delaminating sites of ink jet laminated prints.

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

Bond Strength and Interfacial Adhesion

The bond strength of a laminate essentially 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.[7,8] Figure 1 presents five possible modes of failure: 1) debonding of the ink jet layer from the substrate, 2) debonding of the adhesive from the ink jet layer, 3) debonding of the adhesive from the laminating film, 4-5) the substrate or film failure - tear. The failure of the laminate will occur at its weakest link. It is generally desirable to have high bond strength to the substrate with failure occurring as the adhesive debonds from the ink jet layer.

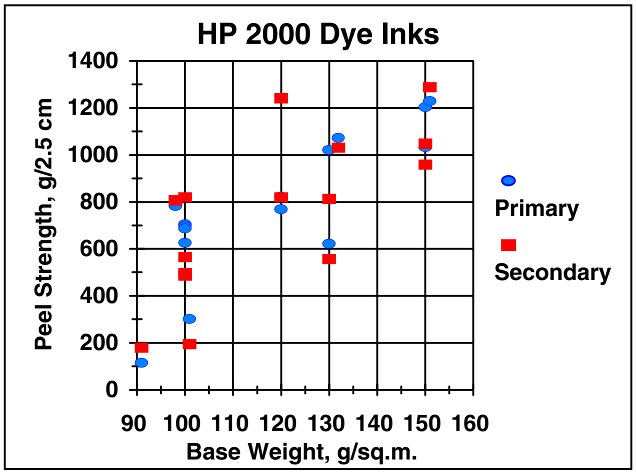
Results and Discussion

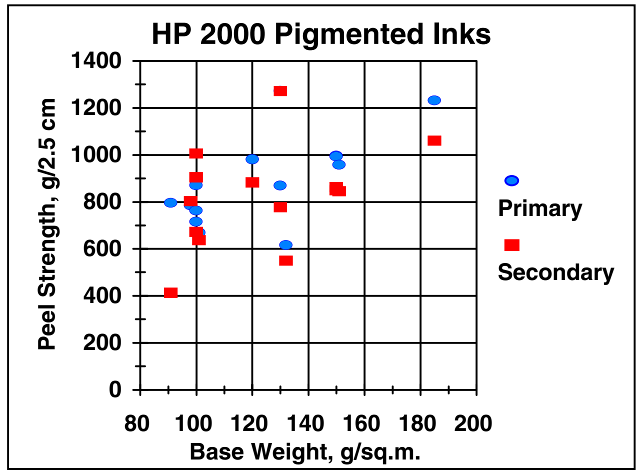
Lamination of Graphic Art Matte Bond Papers

Fourteen different commercially available ink jet matte papers for graphic arts, made by six manufactures, were imaged on a HP 2000 printer with dye and pigmented inks. The printed sheets were laminated with 3 mil glossy film at optimum laminating conditions 24 hours after printing. The applied temperature was selected according to the results from previous experiments.[6]

Figures 2&3 represent the peel strength of primary and secondary colors determined as an average for HP 2000 printer with dye and pigmented inks. The data are scattered but it is seen that adhesion rises with an increase in paper base weight. Peel strength increases from 200 g/2.54 cm for 90 g/m^2 paper base to 1300 g/2.54 cm for 150 g/m^2 paper. This is an equivalent of very good lamination for secondary colors. The peel strength for low weight paper base is higher for HP 2000 pigmented inks than dye inks (400 versus 200 g/2.54 cm). However, the absolute numbers can be misleading because the measured numbers represent two different phenomena. Pigmented inks stay on the surface of paper and delamination occurs from the ink jet coated layer. Dye inks penetrate into ink jet layer and are absorbed by paper. They weaken the paper structure and in the delamination test base paper is torn apart. The more comprehensive explanation will be presented in the chapter entitled "Paper Base Selection".

The effect of paper base weight on adhesion is better seen comparing two ink jet papers of different base weights made by the same company (Table 1). We assumed that companies manufacturing these bonds used raw paper bases from the same source (similar paper sizing agents) and the same ink jet receiving layers. It is seen that, with the exemption of manufacturer II, peel strength nearly doubles with an increase in paper base weight from about 100 g/m^2 to 150 g/m^2.





Figures 2&3. Peel strength for different commercial ink jet matte papers printed on HP 2000 with dye and pigmented inks and laminated.

Table 1. The peel strength comparison of two different paper grades made by five manufactures. Commercial matte ink jet papers were printed on HP 2000 printer with dye inks and laminated.

Manufacturer	I		II		III		IV		V	
Weight g/m^2	100	150	98	132	100	150	101	151	120	185
Colors	Peel Strength, g/2.54 cm									
Primary	687	1072	781	622	665	1203	302	1033	769	1229
Secondary	820	1031	807	558	527	1048	194	959	1241	1289
Unprinted	327	962	611	456	490	782	250	745	432	1111

The results show that lamination to unprinted areas of paper bonds is the most important factor in ultimate lamination and determines adhesion to the printed areas. Higher laminations were observed in the unprinted areas of heavier than of lighter grades. It is also true for printed areas. Generally, the adhesion to unprinted areas of ink jet papers is lower than to printed areas. For lighter weight papers (manufacturers I and V) the difference between unprinted areas and primary colors is nearly double. For these grades secondary colors show higher lamination than primary colors. At higher base weights (150 g/m^2) the difference between unprinted areas, secondary and primary colors diminishes significantly or disappears.

In ink jet matte papers a higher adhesion of the laminating film to primary and secondary colors than unprinted areas is an indication that the ink jet inks improve lamination. Inks are mostly absorbed by pigments in the ink jet receiving layer. It frees some amount of binder associated with pigment facilitating creation of the physical bonds between the binder in the ink jet receiving layer and the laminating film. Dye ink jet inks penetrate deeply into paper bases and at an optimum coat weight the ink jet layer basically prevents excessive spread and wacking of inks. The amount of ink deposited on paper is essentially dependent on the printing mode. The interaction between cellulose fibers and ink jet inks is lower for heavy papers than lighter grades at equal coat weights. It should reduce lamination but reverse effect was observed. The relationship between peel strength and paper base weight is a complex phenomenon and requires additional studies.

Most commercial papers tested in this study had very good or at least decent print quality. The significant difference in the adhesion data presented before is an indication that they were not optimized with respect to lamination. Paper bonds with higher base weight are more dimensionally stable (less puckering and head strikes) and frequently are a choice of customers though at a higher price. As a rule of thumb it can be said that heavy weight papers give better lamination. Both these factors should be indicators to selecting the right paper media for a specific job. It is still a challenge to develop media with good laminating characteristic.

Lamination of Commercial CAD Matte Bond Papers

Most ink jet paper bonds used for CAD and engineering graphics applications are 90 g/m^2 (24 lb text). Six different commercially available matte coated bond papers, made by four manufacturers, were imaged on HP

750 and 1055 printers with dye inks. The printed sheets were subsequently laminated with 3 mil glossy film at optimum conditions. The lamination data for six media are presented in Table 2 in the order of increasing peel strength. The same pattern is observed for both printers although they uses different inks, size of drops and printing speed. The adhesion numbers for CAD ink jet bonds are in wider range than for graphic art paper bonds comparing at the same base weight. Peel strength is such low as 160-200 g/2.54 cm for ink jet bond **a** and such high as 1200-1300 g/2.54 cm for paper **f**.

Manufacturers II and IV produced two types of CAD bonds: one with water fastness and another without water fastness. The media with water fastness (**b** and **e**) have significantly lower peel strength than media without water fastness (**c** and **f**). Generally, in water fast media top ink jet layer is porous and contains a high amount of pigment facilitating quick transport of inks from the surface. It was already shown by authors that excessive amount of pigment in the ink jet layer reduces lamination (6).

Once again, it is seen that CAD media were not optimized with regard to lamination. CAD bonds were developed traditionally for line drawing but with time as ink jet technology advanced people started to use CAD media for GA applications. A good example is HP 1055 printer developed for engineering graphics and now is also used for graphic jobs. Very soon lamination will become a challenge for CAD media and light base weight papers.

Paper Base Selection

Polyethylene coated paper, polypropylene paper and polyester film are examples of non-permeable substrates. Generally, the adhesion of the ink jet layer to these bases is higher than to laminating film. It can be assumed that peel strength of the laminating film to the ink jet layer applied on non-permeable substrates should be similar at the same coat weight. It was shown in the previous chapters that for porous substrate such as paper properties of raw base have an effect on final adhesion of the lamination film to the coated paper.

Table 2. The comparison of peel strength for six commercial CAD ink jet papers printed on HP 750 and HP 1055 printers with dye inks and laminated.

Printers	Manufacturer	I	II		III	IV	
	Colors	a	b	c	d	e	f
HP 750	**Primary**	**299**	**363**	**425**	**723**	**798**	**1293**
	Secondary	191	378	242	980	464	1239
	Unprinted	160	425	247	747	987	1206
HP 1055CM	**Primary**	**207**	**410**	**747**	**752**	**920**	**1189**
	Secondary	177	554	815	739	904	1082
	Unprinted	168	478	803	629	1024	1250

Table 3. The comparison of peel strength for different raw base papers coated with formula I and II (5 g/m^2), printed on HP 750 and HP 1055 and laminated. Data in italic are an indication of tearing paper base.

Paper Bases		A	*B*	C	D	*B*
HST Sizing, s		**100**	**120**	**120**	**5000**	**120**
Formula		I				*II*
Printer	Colors	Peel Strength, g/2.54 cm				
HP 755 CM	Primary	201	*244*	743	615	*115*
	Secondary	186	*145*	749	602	*112*
	Unprinted	172	*180*	773	580	*108*
HP 1055CM	Primary	189	*207*	612	496	*100*
	Secondary	171	*177*	655	645	*107*
	Unprinted	205	*168*	715	564	*108*

Several raw paper bases about 90 g/m^2 were coated with formula I (pigment to binder ratio was 4:1) in the amount of 5 g/m^2. Hercules Sizing Number of these bases was in the range of 120 seconds for paper B and C to > 5000 seconds for paper D. The coated papers were imaged on HP 750 and HP 1055 printers and laminated. The lamination data are presented in Table 3. It is seen that peel strength is strongly dependent on the type of paper base. Paper D has much higher sizing number than paper C (120 and > 5000, respectively) but lamination data are relatively close (750 and 600 g/2.54 cm). On the other hand, papers B and C have nearly identical HST numbers (about 120) but peel strength of the second base is two times higher than first one (200 and 750 g/2.54 cm). It worth to mention that recorded data for paper B represented internal delamination of paper (tearing cellulose fibers apart). Paper A has low surface sizing (HST about 100 seconds) and peel strength is in the range 170-200 g/2.54 cm.

Paper B was also coated with formula II (pigment to binder ratio 1:1), printed and subsequently laminated. Higher amount of binder in the formula prevents pigment separation during coating process and its accumulation on paper surface. Once again, peel strength numbers are very low (about 100 g/2.54 cm) and the weakest is internal structure of the paper because cellulose fibers are torn apart.

The data above show that HST sizing numbers for tested papers do not correlate with lamination data. It means that chemical interaction of ink dyes (glycols) with particular sizing agent makes paper weaker and in extreme case we observe tearing apart cellulose fibers. Paper sheet can also have different degree of absorbing particular chemicals from ink jet ink and it can change the peel strength.

Most of ink jet media was developed to maximize color gamut, reduce dry time, eliminate intercolor bleed and reduce tack at high relative humidity. Some of them have acceptable lamination properties especially with dye inks. Generally, it is possible to develop media with excellent lamination properties but inferior density of colors and color gamut. Close collaboration is needed between those formulating chemists developing ink jet receiving coatings for the media and chemists designing adhesives for laminating films to understand all consequences of interactions between the ink receptive layer and lamination adhesive.

Conclusions

The paper discussed several factors influencing the design of ink jet media in respect to lamination. It was shown, base on evaluation of a dozen of commercial ink jet matte bond papers, that the lamination increased with paper weight. Several paper raw bases 90 g/m^2 were coated with ink jet formula, printed and laminated. The peel strength was dependent on the type and characteristic of raw base paper though the same coat weight was applied. It was found that an interaction of inks with sizing agents could significantly reduce internal strength of paper.

Reference

1. Fred Noll, *The U.S. 1998 Electronic Printing Report Series*, "Ink Jet Printing," Part 1, page 117
2. Schuurmans H., The Chemistry and Physics of Laminating & Finishing, *DPI '98 Annual Conference, Seminar T-,* Orlando, FL 1998
3. Franks B., Finishing Ink Jet Prints - The User's View, *DPI 2000 Annual Conference, Seminar T-09,* Dallas 2000
4. Mann T and Wolf J., Results: Media, Inks and Lamination, *DPI 2000 Annual Conference, Seminar T-07,* Dallas 2000
5. Graczyk T. and Xie B., Thermal Lamination of Photo Paper, *NIP15: International Conference on Digital Printing Technologies, IS&T, Springfield, VA,* 1999, p.176
6. Graczyk T. and Xie B., Lamination Study of Ink Jet Media, Tappi J. 83, 6, 63 (2000)
7. TAPPI Test Methods, "*Determination of thermoplastic coating adhesion to non-porous substrates,"* T 540 om-93
8. TAPPI Test Methods, "*Determination of thermoplastic coating adhesion to non-porous substrates,"* T 540 om-93

Biography

Tom Graczyk received his Master's 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.