LAMINATION OF ELECTROPHOTOGRAPHIC PRINTS

Bohumil Jašúrek, Jan Vališ, Michaela Šrámková
University of Pardubice, Faculty of Chemical Technology, Department of Graphic Arts and Photophysics, Pardubice, Czech Republic

Abstract: *Lamination of electrophotographic prints is more problematic than lamination of prints from conventional printing techniques as is for example offset printing. The main problem is worse adhesion of laminating films and due to partial or full delamination can occurs when prints are mechanically stressed. Often problem is also creation of optical effect called silvering. The aim of this work was to compare adhesion of two laminating films (PKCCO BOPP Thermal Laminating Film and Derprosa™ Matte Premier) to prints from different electrophotographic printers (e.g. Xerox, Canon, Konica-Minolta). The lamination conditions were as follows: lamination speeds 10 and 20 m/min, application temperature 120 ˚C and lamination pressure 400 kPa. The adhesion of the laminating film was evaluated by a Peel tester 1 hour, 1 day and 14 days after lamination. The quality of the lamination after the grooving and bending test was evaluated visually. The last measured parameter was colour difference between laminated and non-laminated prints and this parameter was evaluated 1 hour and 14 days after lamination.*

Key words: lamination, electrophotography, adhesion, peel test, colour difference, grooving

1. INTRODUCTION

Lamination is finishing process in printing where thin polymeric film is bind to paper or cardboard mostly by pressure or heat. Lamination of prints is generally used to protect papers/cardboards from general wear and tear, improve the longevity of prints and to improve the appearance of prints. Amorphous thermoplastic polymer films such as polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), polyamide (PA), polyvinyl chloride (PVC) or others are used for lamination. There are many different types of laminating films differing in appearance (matte, glossy, velvety, textured, holographic, etc.), useful properties (e.g. barrier properties, increase of light-fastness), thickness, etc. Laminating film is bind with prints by adhesive. The used adhesives must meet several basic parameters. In particular, it is a matter of ensuring good adhesion of both materials (print and laminating film), they must be sufficiently clear, flexible and must not react with inks. Four basic types of adhesives are used: hot melt adhesives, dispersion adhesives, pressure sensitive adhesives and UV-curable adhesives.
In terms of technology, there are cold lamination, hot lamination and lamination with using of UV radiation. Cold lamination takes place at room or slightly elevated temperature (usually 30–40 ° C) using pressure sensitive adhesives (dry lamination) or using water-based acrylic adhesives (wet lamination). Hot melt adhesives are used for hot lamination. Hot melts are pre-applied to the polymer films and activated by heating (usually 90–130 °C). Hot melt adhesives are thermoplastic materials that are solid at room temperature (solvent-free) and become tacky when heated. Hot melt adhesives based on EVA (ethylene-vinyl acetate) copolymer are most often used. UV curable adhesives contain reactive monomers, oligomers and photoinitiators. After UV exposition, polymerization reaction starts (mostly free radical polymerization) and liquid adhesive is change to solid-state in fraction of second and connect laminating film with print.
The quality of lamination depends on several parameters, the most important are the settings of the laminating equipment (temperature, pressure, speed), type of laminating film and adhesive, printed product (printed material, type of ink, tone value, etc.) and time between lamination and printing.
Lamination of prints can be accompanied by a number of problems due to the interaction of the laminating films, adhesives, printing inks and the printed materials. Defects can occur both in appearance (e.g. uneven gloss, change of color, silvering) and in the useful properties of the laminated product (insufficient adhesion, cracking, waviness, etc.). If the inks are insufficiently dried, wrinkles may appear immediately after lamination or at longer interval. In addition, components (solvents, dyes, pigments, etc.) of non-dried inks can diffuse through the paper to the other side of the sheet (unlaminated). For porous materials, the adhesive may also diffuse and the sheets may stick together.
Prints from many printing techniques are laminated, such as offset, screen-printing, flexographic printing and also digital printing. Lamination of prints from digital printing presses (especially from electrophotography) is generally more problematic and there are problems mainly with worse adhesion

of laminating films. The result is local/full delamination, which occurs especially in places where prints are mechanically stressed (e.g. grooving, bending, etc.). The reason is a different type of ink (digital electrophotography uses powder toner) and the thickness of printed layer (tens of micrometers in case of electrophotographic print (Schleusener & Volkhard, 2006) vs. few micrometers (Kipphan, 2001) in case of offset or flexographic printing).
The aim of this work was to compare adhesion of two laminating films (PKCCO BOPP Thermal Laminating Film and Derprosa™ Matte Premier) to prints from different electrophotographic printers (Canon, HP Indigo, Konica-Minolta, Xeikon and Xerox). The adhesion of laminating films to prints was evaluated by a Peel tester 1 hour, 1 day and 14 days after lamination.

2. MATERIALS AND METHODS

Seven different printing presses were used for preparation of prints for lamination. They are listed in Table 1 together with used cardboards (all cardboards are coated and their grammage is between 150 and 300 g/m^2). Two sets of printed samples were prepared in case of HP Indigo Press WS6800 (with and without primer DigiPrime® 680). DigiPrime® 680 improves the transfer and adhesion of HP Indigo Electroinks. Figure 1 shows a printing sheet (format SRA3, 320×450 mm) for lamination quality evaluation. The adhesion of laminated sheets for the individual printing presses was evaluated on green strips (30×180 mm).

Table 1: Printing presses and used cardboards

Printing presses	Cardboard (grammage)
Canon imagePRESS C710	Top Coated Graphic$^+$ Silk (200 g/m^2)
HP Indigo Press WS6800	MC Elite 2S-200 FSC (200 g/m^2)
Konica Minolta Accurio Press c3070	MultiArt Silk Matt (150 g/m^2)
Xeikon 8000	Color Copy (250 g/m^2)
Xerox c1000i	MultiArt Silk Matt (150 g/m^2)
Xerox Color C75 Press	Color Copy (300 g/m^2)
Xerox Iridesse Production Press	Color Copy Coated (170 g/m^2)

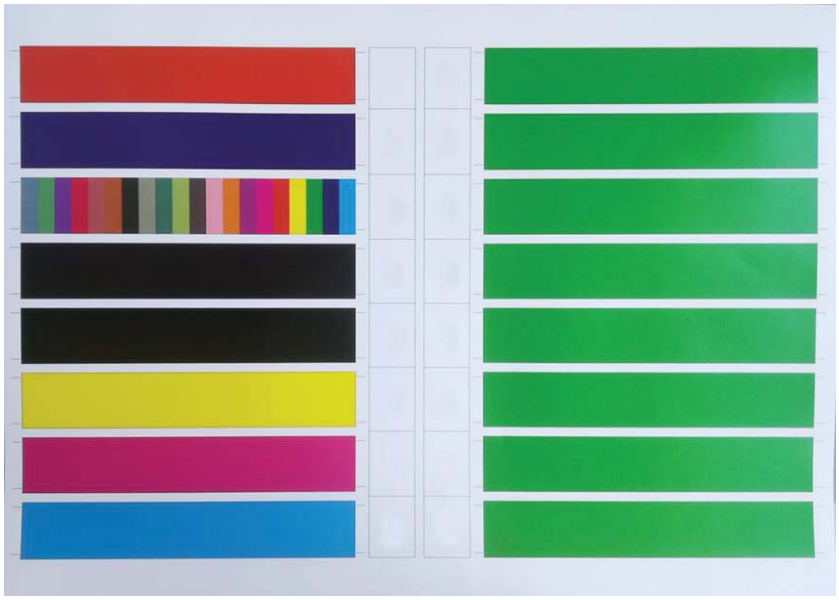

Figure 1: Printed sheet for evaluation of lamination adhesion

Lamination of printed sheets was done with laminator Amiga 52 (hot lamination) from company KOMFI. Two lamination films were used. First one is Derprosa™ Matte Premier (thickness 35 µm) that is mostly used for lamination of electrophotographic prints. Second one was PKCCO BOPP Thermal Laminating Film

(thickness 24 µm) mostly used for lamination of offset printings. Conditions of lamination were as follows: lamination temperature 120 °C, lamination pressure 400 kPa, lamination speed (10 and 20 m/min.).
A Peel tester from company KOMFI (software K-UG-02, KOMFI) was used for evaluation of lamination film adhesion. The evaluated parameter was the weight required to peel the laminating film from the printing sheet. Set parameters were as follows: peel-off length 150 mm, peel-off speed 250 mm/min. The adhesion of the laminating film was evaluated 1 hour, 1 day and 14 days after lamination. Eight strips for every printing press were used for calculation of average weight needed for peel off the laminating film. Evaluation of peeling force of a T-shaped bonded assembly of two flexible adherends by a T-peel test is described in ISO 11339:2010 (International Organization for Standardization, 2010).
The grooving of the samples was performed by a grooving machine GMP 450 SA (Cyklos Choltice). The grooving tool had a U profile (depth 0.7 mm, width 1.4 mm).
Color difference (ΔE^*_{76}) between laminated and non-laminated prints was evaluated by spectrophotometer Konica Minolta FD-5 (1 hour and 14 days after lamination). Measured parameters were L^*, a^*, b^* coordinates of CIELAB colour space. From these coordinates was calculated the colour difference ΔE^*_{76} (Equation 1). The reference material for the calculation of ΔE^*_{76} was the non-laminated prints.

$$\Delta E^*_{76} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

ΔL^* is the difference of coordinates L* of laminated and non-laminated sample
Δa^* is the difference of coordinates a* of laminated and non-laminated sample
Δb^* is the difference of coordinates b* of laminated and non-laminated sample

3. RESULTS AND DISCUSSION

Tables 2 and 3 summarize results of Peel test. Measured parameter was weight needed to peel off the laminating film from green strips (see Figure 1). In general, samples from the HP Indigo Press WS6800 printing press (with/without primer) have the lowest adhesion for both laminating film. The use of a primer increased the adhesion of the PKCCO BOOPP Thermal Laminating Film, but in case of Derprosa™ Matte Premier were results similar. Better results of laminating film adhesion were obtained with lower lamination speed (10 m/min). Larger differences between adhesion (lamination speed 10 or 20 m/min) are in case of Derprosa™ Matte Premier laminating film, where at a lamination speed of 20 m/min, the weights required to peel off the laminating film are only in tens of grams (except samples of Canon imagePRESS C710 and Xeikon 8000). At a lamination speed of 10 m/min, the weight required for peeling off the laminating film is most often in the range of 500–900 g.
For Derprosa™ Matte Premier laminating film, larger differences in adhesion were found for different printing presses (best results Canon imagePRESS C710, Konica Minolta Accurio Press c3070 and Xerox Color C75 Press). In the case of PKCCO BOPP Thermal Laminating Film, the results of different printing presses were similar (for both lamination speeds mostly between 400 and 700 g).

Table 2: Average weight (w) required for peel off the Derprosa™ Matte Premier laminating film 1 hour, 1 day and 14 days after lamination, lamination speed 10 and 20 m/min, tested green strips, σ - standard deviation.

	1 hour		1 day				14 days			
	10 m/min		10 m/min		20 m/min		10 m/min		20 m/min	
	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)
Canon imagePRESS C710	907	76	944	55	828	44	967	53	978	54
Konica Minolta Accurio Press c3070	824	44	835	50	46	7	875	33	66	5
Xeikon 8000	588	43	716	43	635	43	743	37	710	35
Xerox c1000i	504	45	511	49	18	6	479	19	40	4
Xerox Color C75 Press	837	65	907	62	86	7	991	60	101	8
Xerox Iridesse Production Press	455	83	743	71	10	4	660	67	32	4
HP Indigo Press WS6800	294	12	209	21	87	14	222	15	117	11
HP Indigo Press WS6800 (primer)	torn film		204	10	96	15	225	14	151	16

Table 3: Average weight (w) required for peel off the PKCCO BOPP Thermal Laminating Film 1 hour, 1 day and 14 days after lamination, lamination speed 10 and 20 m/min, tested green strips, σ - standard deviation.

	1 hour				1 day				14 days			
	10 m/min		20 m/min		10 m/min		20 m/min		10 m/min		20 m/min	
	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)
Canon imagePRESS C710	515	13	406	13	584	12	438	5	660	13	499	11
Konica Minolta Accurio Press c3070	527	9	387	8	596	8	458	15	735	10	523	14
Xeikon 8000	459	18	345	13	576	26	474	13	677	26	560	13
Xerox c1000i	600	26	372	25	687	16	548	18	797	18	444	17
Xerox Color C75 Press	415	29	345	18	484	28	376	11	696	29	494	12
Xerox Iridesse Production Press	612	38	494	27	697	39	513	21	799	38	589	21
HP Indigo Press WS6800	306	23	218	18	340	26	227	8	459	27	272	10
HP Indigo Press WS6800 (primer)	518	20	439	24	601	23	447	7	749	24	523	10

The adhesion of the PKCCO BOPP Thermal Laminating Film increased with increasing time interval from lamination (1 hour, 1 day, 14 days). In the case of Derprosa™ Matte Premier laminating film, the results were similar or the increase was not so significant.
Table 4 summarizes the results of adhesion of PKCCO BOPP Thermal Laminating Film 1 hour and 1 day after lamination (green strips, lamination speed 10 m/min), where laminated prints were before peel test irradiated by medium pressure mercury lamp (160 W/cm, belt speed 10 m/min). Samples irradiated by medium pressure mercury lamp (Table 4) are marked "After Ir.". It is clear from the results that after irradiation, there was a significant increase in the adhesion of the laminating film in almost all printing technologies, with the exception of HP Indigo Press WS6800 (without primer).

Table 4: Average weight (w) required for peel off the PKCCO BOPP Thermal Laminating Film 1 hour and 1 day after lamination (samples irradiated after lamination by medium pressure mercury lamps – "After Ir."). Lamination speed 10 m/min. Tested green strips. σ - standard deviation.

	1 hour				1 day			
	Without Ir.		After Ir.		Without Ir.		After Ir.	
	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)	w (g)	σ (g)
Canon imagePRESS C710	515	13	870	30	584	12	907	35
Konica Minolta Accurio Press c3070	527	9	812	53	596	8	903	54
Xeikon 8000	459	18	673	31	576	26	694	21
Xerox c1000i	600	26	1334	59	687	16	1322	54
Xerox Color C75 Press	415	29	1046	33	484	28	1022	21
Xerox Iridesse Production Press	612	39	1526	78	697	39	1595	54
HP Indigo Press WS6800	306	23	279	18	340	26	345	15
HP Indigo Press WS6800 (primer)	518	20	661	24	601	23	768	29

Tables 5 and 6 show results of grooving of laminated prints for both laminating films. The evaluation of grooving was performed visually according to a five-point scale (0 – no defects after grooving, 1 – minimal (local) silvering at the groove, 2 – slight silvering along the entire length of the groove, 3 – delamination/extensive silvering along the entire length of the groove, 4 – delamination/extensive silvering along the entire length of the groove, which further extends beyond the groove area). Similar behavior was observed for the CMYK process colors and others for the colors (red-R, blue-B, black-K_{CMY}) created by overprinting of process colors. For both laminating films, the CMYK process colors showed less

defects and lower damage than the colors prepared by their overprinting. The reason is probably the thickness of the ink layer. In the overall comparison of both laminating films with all printing presses, PKCCO BOPP Thermal Laminating Film shows less defects.

Table 5: Grooving of laminated prints (Derprosa™ Matte Premier), lamination speed 10 m/min, CMYK (process inks), RBK_{CMY} (red, blue, black)

	10 m/min				20 m/min			
	Grooving		Grooving & Bending		Grooving		Grooving & Bending	
	CMYK	RBK_{CMY}	CMYK	RBK_{CMY}	CMYK	RBK_{CMY}	CMYK	RBK_{CMY}
Canon imagePRESS C710	0	0	0	0	0	0	0	1
Konica Minolta Accurio Press c3070	0	0	0	0	0	0	2	3
Xeikon 8000	0	0	0	0	0	0	0	0
Xerox c1000i	0	0	0	1	0	0	2	3
Xerox Color C75 Press	0	0	0	0	0	0	1	1
Xerox Iridesse Production Press	0	0	0	0	0	1	2	1
HP Indigo Press WS6800	0	0	2	4	0	0	3	4
HP Indigo Press WS6800 (primer)	0	0	1	3	0	0	3	4

Table 6: Grooving of laminated prints (PKCCO BOPP Thermal Laminating Film), lamination speed 10 m/min, CMYK (process inks), RBK_{CMY} (red, blue, black)

	10 m/min				20 m/min			
	Grooving		Grooving & Bending		Grooving		Grooving & Bending	
	CMYK	RBK_{CMY}	CMYK	RBK_{CMY}	CMYK	RBK_{CMY}	CMYK	RBK_{CMY}
Canon imagePRESS C710	0	0	0	0	0	0	1	1
Konica Minolta Accurio Press c3070	0	0	0	0	0	0	0	1
Xeikon 8000	0	0	0	0	0	0	0	0
Xerox c1000i	0	0	0	0	0	0	1	1
Xerox Color C75 Press	0	0	0	0	0	0	0	0
Xerox Iridesse Production Press	0	0	0	0	0	0	0	1
HP Indigo Press WS6800	0	0	0	0	0	0	0	0
HP Indigo Press WS6800 (primer)	0	0	0	0	0	0	0	0

The last parameter evaluated was the color changes of CMYK process colors after lamination. Color difference (ΔE^*_{76}) was evaluated 1 hour and 14 days after lamination. The measured color differences for both lamination films are given in Tables 7 and 8. For PKCCO BOPP Thermal Laminating Film, the color difference was mostly up to 3. The exception are prints from the Xeikon 8000 printing press, for which the color difference was in the range of 4.1–10.5. The opposite behavior was observed with the lamination film Derprosa™ Matte Premier, where the prints from Xeikon 8000 had the lowest color differences (0.7–1.8). The color difference of other prints ranged from 2.7 to 12.2.

Table 7: Color difference (ΔE^*_{76}) of laminated prints 1 hour and 14 days after lamination (Derprosa™ Matte Premier)

	ΔE^*_{76}							
	C		M		Y		K	
	1 hour	14 days	1 hour	14 days	1 hour	14 days	1 hour	14 days
Canon imagePRESS C710	3.5	3.6	6.7	6.9	7.8	8.1	11.8	12.2
Konica Minolta Accurio Press c3070	3.6	4.1	4.9	5.6	5.9	6.7	8.8	10.1
Xeikon 8000	1.0	1.1	0.7	1.6	1.3	1.8	1.2	1.8
Xerox c1000i	4.0	4.8	4.1	4.9	7.5	8.3	7.7	8.9
Xerox Color C75 Press	2.7	3.0	3.8	4.5	4.7	4.8	4.4	6.9
Xerox Iridesse Production Press	2.9	2.9	4.4	4.8	6.9	7.4	10.2	11.3
HP Indigo Press WS6800	3.0	3.3	3.9	4.4	5.1	5.4	7.4	8.4
HP Indigo Press WS6800 (primer)	3.3	3.5	3.9	4.3	4.4	4.7	7.4	8.8

Table 8: Color difference (ΔE^*_{76}) of laminated prints 1 hour and 14 days after lamination (PKCCO BOPP Thermal Laminating Film)

	ΔE^*_{76}							
	C		M		Y		K	
	1 hour	14 days	1 hour	14 days	1 hour	14 days	1 hour	14 days
Canon imagePRESS C710	0.8	5.1	3.4	3.9	1.6	2.4	0.7	1.7
Konica Minolta Accurio Press c3070	1.0	5.9	0.8	6.7	0.8	3.7	2.5	2.9
Xeikon 8000	4.1	4.1	6.1	6.1	7.8	7.9	10.4	10.5
Xerox c1000i	2.6	2.7	2.3	3.2	1.6	1.8	2.9	3.4
Xerox Color C75 Press	0.9	0.9	1.2	1.6	2.4	2.4	3.0	3.2
Xerox Iridesse Production Press	2.3	2.4	1.0	1.3	2.5	2.7	1.3	1.5
HP Indigo Press WS6800	1.4	1.6	0.4	0.5	0.7	0.8	2.5	2.7
HP Indigo Press WS6800 (primer)	0.8	0.9	1.5	1.6	0.7	0.8	0.9	1.3

4. CONCLUSIONS

The aim of this work was to evaluate the quality of lamination of electrophotographic prints of various printing presses. In particular, the adhesion of the laminating film to prints and defects caused by grooving and bending were evaluated. The measured values of adhesion of laminating films for electrophotographic printing presses show the importance of choosing a suitable laminating film and optimization of the lamination conditions for individual printing presses to achieve sufficient adhesion between the laminating film and prints, which will not cause defects of laminating prints. For each type of laminating film, it is necessary to find suitable parameters of lamination (temperature, pressure, speed) and, if necessary, adjust them for a specific type of print (printer, type of toner).

The best adhesion results of Derprosa Matte Premier laminating film were achieved with prints from Canon image PRESS C710, Konica Minolta Accurio Press c3070 and Xerox Color C75 Press. In the case of PKCCO BOPP Thermal Laminating Film, the differences between the adhesion results of the evaluated printing presses were not large, with the exception of the HP Indigo Press WS6800 without the use of a primer (lower adhesion of the laminating film).

In terms of the color change of the laminated print, DerprosaTM Matte Premier for lamination of prints from the Xeikon 8000 can be recommended and PKCCO BOPP Thermal Laminating Film for lamination of prints from other evaluated printing presses (except Xeikon 8000) can be recommended.

5. REFERENCES

International Organization for Standardization. (2010) ISO 11339:2010. Adhesives - T-peel test for flexible-to-flexible bonded assemblies. International Organization for Standardization.

Kipphan, H. (2001) *Handbook of print media: technologies and production methods*. Berlin. Springer.

Schleusener, M. & Volkhard M. (2006) Electrophotohraphy and OCÉ Direct Imaging. In: Hoffmann-Falk M. (ed.) *OCÉ Digital Printing*. Poing, Océ Printing Systems, pp. 199–245.