

Protection of print on labels with various overprint varnishes

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Short abstract

Label stock was flexo printed, and the print was protected with overprint varnish (OPV). Three different OPV formulations were flexo-printed on the surface of flexo printed label design. Three assorted aniloxes with different resolutions and volumes were employed. A Taber abrasion tester was utilized to examine OPV durability. Taber adhesion testing resulted in the conclusion that among three different commercial overprint varnishes, OPV 2024 gave the best protection when using an anilox of 360 LPI resolution with volume 6.0 BCM, which means that this anilox deposited the thickest layer of overprint varnish. The OPV 2024 had the same components as OPV 2020, plus acylated polysiloxanes and pentaerythritol esters, which made this formulation the most powerful varnish for label design protection.

Keywords: flexographic printing, labels, anilox resolution and volume, adhesion, Taber abrasion tester

1. Introduction and background

Flexographic printing of labels is a very large and important market, and it was estimated that about 75% of label printing is done by this printing process (Izdebska, 2016). Flexography is a relief process (Figure 1), meaning it prints from plates employing raised images on photopolymer plates. Plates print directly to the image with a very light impression. Inks for flexography are very fluid, in the range of 100 cP. Printed dots are much larger than in lithography and are often perfectly round. A schematic of the possible setup for the flexo printing unit is shown in Figure 1.

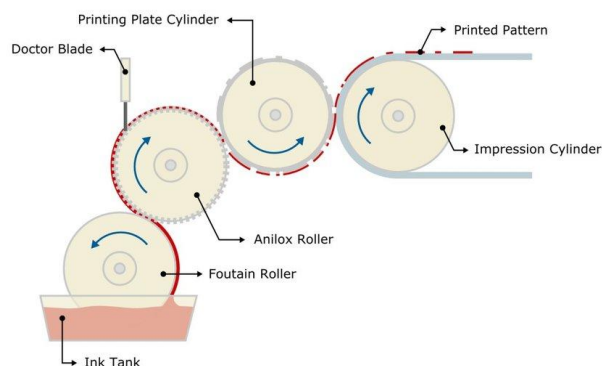


Figure 1: Schematic of flexo printing unit

Flexographic printing of labels has many advantages because it is faster and cheaper than digital printing and can be combined with finishing operations such as embossing and die cutting. Labels bring important information about particular products, they come in various sizes and shapes and are very often printed with spot colors but may also use extended color gamut colors such as

CMYKOGV, which can usually match about 90% of Pantone colors. Printing with extended color gamut inks offers ink savings and shorter time between print jobs. To be more environmentally sound, water-based inks are often used. The replacement of petrochemical-based ink formulations with water-based ones reduces the creation of volatile organic compounds. To reduce VOC emissions, water-based inks are widely used in both conventional and digital rotogravure, flexography, screen printing, and digital printing processes. The water-based inks have achieved comparable print quality as solvent-based inks do. Today, water-based inks contain 90% to 95% less VOCs than solvent-based inks (Kliopova-Galickaja and Kliugaite, 2018). The ingredients of most commercial water-based inks include a synthetic colorant, acrylic resin, water, and additives. The acrylic resin-based inks yield better color reproduction and brightness, which is the main reason why they are widely applied in the printing industry (Christie and Abel, 2021; Szabo, 2002). In printing ink, it is the resin that determines ink durability, adhesion, and abrasion resistance. Therefore, it is crucial to choose high-quality resins for packaging inks and printed labels because scratches and thin shallow cuts degrade the appearance of the print. Also, during manufacturing, as the printed piece moves on conveyors, its slip or coefficient of friction can be too large or too small, harming the proper processability and finishing of printed pieces. Thus, to improve processability, extend the life of the label, and enhance the color properties (Cigula and Donevski, 2022) or ensure the same properties of printed colors on the label surface, such as coefficient of friction, label or other packaging products are overprinted with overprint varnish (OPV). OPVs can be water-based, popular because of their fast-drying times, flexibility, resistance to yellowing, and compatibility with many substrates. Water-based OPVs are based on acrylic, styrene-acrylic, or polyester chemistry.

OPVs can be energy-curable, which provides excellent smoothness and gloss. They consist of photoinitiators, monomers, and oligomers curing under UV or LED light and provide great abrasion resistance. There are attempts to use biodegradable overprint varnishes (Bozhkova et al., 2015). Another OPV chemistry is polyurethane based. These OPVs offer great abrasion resistance and durability. Depending on the visual appearance, varnishes may be glossy or matte. Varnishes shift slightly and enhance the color sensation of the underlying print (Cigula and Donevski, 2022). Besides the main chemistry of OPV varnishes represented by various polymers, they also may contain slip agents, UV stabilizers, antimicrobial agents, matting agents, and other additives.

The goal of the current work was to investigate and prove which overprint varnish chemistry and what anilox, meaning what overprint varnish thickness, is the most suitable option for protecting the print on the label.

2. Materials and methods

2.1 Flexo printing of labels

The construction of a label has three components: the primer, the inks creating the design, and the overprint varnish (OPV). The label stock used was from Green Bay Packaging, WI. All the primer and flexographic inks were printed with the same type of anilox, 360 LPI resolution, and 5.0 BCM volume before applying the OPV varnish. Printing was done on Mark Andy Comco Commander Flexo press. Water-based flexo spot color inks were used at 50cP viscosity. For printing overprint varnish, all three aniloxes (360 LPI resolution and 5.0 BCM volume, 360 LPI /6.0 BCM, and 550 LPI /3.1 BCM) along with three various UV curable overprint varnishes (OPVs) were employed in nine different print runs, one at a time. Commercial OPV varnishes were used, and their chemical composition was as follows:

OPV 2020: Epoxy Acrylate, Oxybis (methyl-2,1-ethanediol) diacrylate, Diacrylate Ester, Benzophenone, Photoinitiator.

OPV 2022: Epoxy Acrylate, oxybis (methyl-2,1-ethanediol) diacrylate, Diacrylate Ester, Photoinitiator, Polyurethane resin.

OPV 2024: Epoxy Acrylate, Oxybis (methyl-2,1-ethanediyl) diacrylate, Diacrylate Ester, Benzophenone, Acrylated Polysiloxanes, Pentaerythritol triacrylate esters, Pentaerythritol tetraacrylate esters. Design of the tested label is shown in Figure 2.

After printing and printability analysis of the samples, abrasion testing was performed with the Taber Abrasion Tester.



Figure 2: Design of the label

2.2 Taber Abrasion

Following are some standard procedures employing Taber abrasion tester:

ASTM F1978: Standard Test Method for Measuring Abrasion Resistance of Metallic Thermal Spray Coatings by Using the Taber Abrasion Tester.

ASTM D4060: Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abrasion Tester

ASTM D1044 - 19: Standard Test Method for Resistance of Transparent Plastics to Surface Abrasion by the Taber Abrasion Tester

ISO 7784: Paints and varnishes — Determination of resistance to abrasion

Part 1: Method with abrasive-paper-covered wheels and rotating test specimen

Part 2: Method with abrasive rubber wheels and rotating test specimen

In our work, Taber abrasion resistance of printed labels overprinted with OPV varnish was tested according to ASTM D4060. The flat specimen was mounted to a turntable, rotating at a fixed speed horizontally. Two arms support abrading wheels, coated with abrasive material. During abrading, the turntable rotates, and the wheels are force-rubbed against the sample. Taber Abrading Wheels CS10, Resilient Wheel Set (Pack of 2) with mild abrasive action, made with rubber and abrasive grain, were employed. The applied weight was 500 g on each side of the wheel during 50 and 100 abrasion cycles.

2.3 Analytical

The optical density of the black print was measured and recorded at the same spot before and after the rub test for each label and the loss of optical density was calculated. CIE LAB was recorded on

black before and after rub and ΔE_{00} was calculated. Spectrodensitometer eXact from X-Rite was employed for all tests, using D50 illuminant and 2° observer. Data were collected at five different positions and their average and standard deviation were calculated. ΔE_{00} was calculated as follows:

$$\Delta E_{00} = \sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right) \left(\frac{\Delta H'}{K_H S_H}\right)}$$

Where:

R_T = A hue rotation term

L^*C^*h = Compensation for neutral colors

S_L = Compensation for lightness

S_C = Compensation for chroma

S_H = Compensation for hue

$$\Delta L_{00} = \frac{\Delta L'}{K_L S_L}$$

$$\Delta C_{00} = \frac{\Delta C''}{S_C}$$

$$\Delta H_{00} = \frac{\Delta H''}{S_H}$$

3. Results and discussion

Rub resistance is one of the most important end-use characteristics of printed inks and overprint varnishes in packaging applications. Particular packaging product is used more than once, and the ink should stay intact within the period the product is in use. Rub resistance is connected with the print quality and durability of ink and overprint varnish. To achieve perfect print quality, legibility of print, and consequently excellent rub resistance, the substrate should have higher surface energy than that of the ink surface tension. If the condition is not fulfilled, the print is not uniform and may be mottled. When the ink dries, the adhesion may be poor, which can be measured as rub resistance. The same applies to the color print, overprinted with the varnish. Multicolor flexo print was overprinted with three different varnishes at three different film thicknesses and their adhesion was determined as a Taber abrasion and Sutherland rub test after 50 and 100 strokes. Each varnish was applied at three different thicknesses using flexo printing with anilox 360 LPI (142 L/cm) resolution and 5.0 BCM (7.75 $\mu\text{m}^3/\mu\text{m}^2$) volume; 360 LPI (142L/cm) /6.0 BCM (9.3 $\mu\text{m}^3/\mu\text{m}^2$) volume, and 550 LPI (217L/cm) /3.1 BCM (4.8 $\mu\text{m}^3/\mu\text{m}^2$) volume. The higher the resolution, the smaller the cell volume, but because aniloxes are made by laser engraving, cells can vary in depth, thus volume. The results clearly show that the finest resolution anilox with the smallest cell volume (550LPI/3.1 BCM) provided the worst protection and thinnest varnish layer, where the optical density on black area after 50 and mainly after 100 strokes dropped the most for all varnishes (Table 1, and Figure 3-6).

Table 1: CIE LAB and optical density of original printed labels printed on Mark Andy flexo press after 50 and 100 Taber abrasion cycles (Print design Red Pepper).

Sample ID #	Red Pepper Label			Red Pepper Label			Red Pepper Label		
Anilox Density	360/5.0	360/5.0	360/5.0	360/6.0	360/6.0	360/6.0	550/3.1	550/3.1	550/3.1
Over Print Varnish (OPV)	OPV 2020	OPV 2022	OPV 2024	OPV 2020	OPV 2022	OPV 2024	OPV 2020	OPV 2022	OPV 2024
Optical Density 0 rub cycles	1.16	1.15	1.15	1.14	1.13	1.13	1.14	1.14	1.13
L	31.76	31.35	32.23	32.54	32.77	31.71	32.10	32.84	32.49
a	0.61	0.74	0.73	0.53	0.65	0.73	0.68	0.66	0.69
b	0.22	0.28	0.15	0.21	0.08	0.25	0.31	0.14	0.16
Optical Density 50 rub cycles	1.13	1.14	1.13	1.13	1.13	1.12	1.09	1.12	1.12
L	32.01	32.51	32.16	32.63	32.42	32.80	32.74	33.82	32.92
a	0.67	0.70	0.69	0.50	0.61	0.64	0.73	0.68	0.72
b	0.06	-0.08	-0.09	-0.11	-0.08	-0.20	-0.16	-0.54	-0.27
Change in Density After 50 Cycles	0.03	0.01	0.02	0.01	0	0.01	0.06	0.02	0.01
Delta E 2000	0.267	0.98	0.1753	0.33	0.32	0.98	0.69	1.03	0.54
Optical Density 100 cycles	1.13	1.13	1.13	1.1	1.13	1.12	0.58	0.73	0.8
L	32.7	32.39	32.53	32.64	32.84	32.89	36.96	39.95	38.02
a	0.66	0.7	0.66	0.46	0.59	0.66	0.65	0.54	0.59
b	0.01	-0.14	-0.24	-0.56	-0.17	-0.26	-0.58	-1.34	-1.24
Change in Density After 100 Cycles	0.03	0.02	0.02	0.04	0.00	0.01	0.56	0.41	0.33
Delta E 2000	0.778	0.92	0.46	0.382	0.266	1.06	4.06	6.13	4.76



*Figure 3: Optical density of label varnished with **OPV2020** varnish and deposited with 360LPI/5.0 BCM anilox, 360LPI/6.0 BCM anilox, and 550LPI/3.1 BCM anilox. Optical density was measured after printing (0), after 50 strokes of Taber abrasion tester (50), and after 100 strokes of Taber abrasion tester*



Figure 4: Optical density of label varnished with **OPV2022** varnish and deposited with 360LPI/5.0 BCM anilox, 360LPI/6.0 BCM anilox, and 550LPI/3.1 BCM anilox. Optical density was measured after printing (0), after 50 strokes of Taber abrasion tester (50), and after 100 strokes of Taber abrasion tester

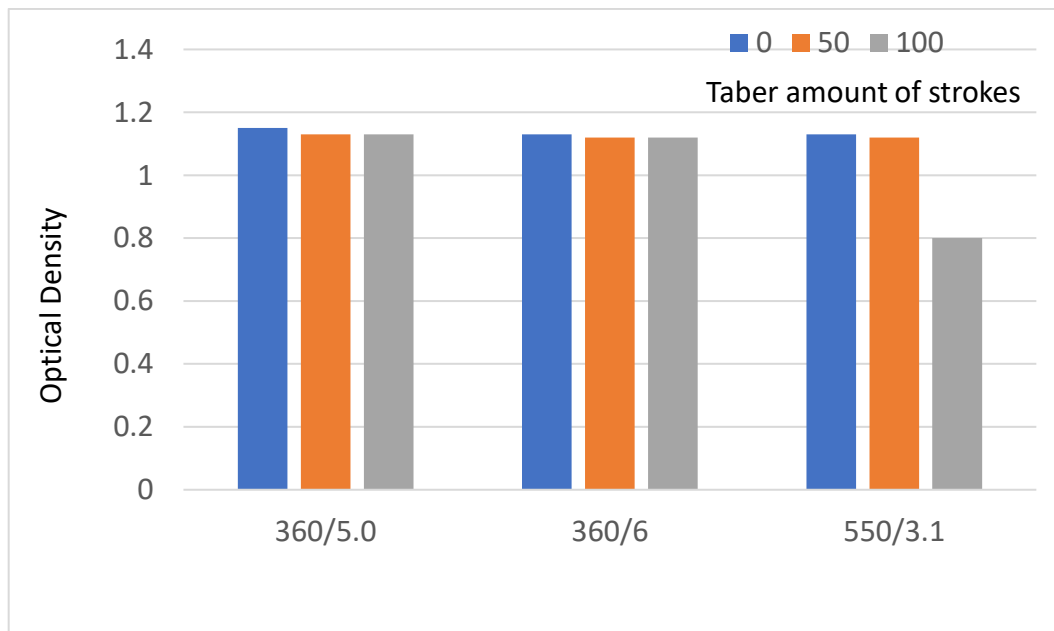


Figure 5: Optical density of label varnished with **OPV2024** varnish and deposited with 360LPI/5.0 BCM anilox, 360LPI/6.0 BCM anilox, and 550LPI/3.1 BCM anilox. Optical density was measured after printing (0), after 50 strokes of Taber abrasion tester (50), and after 100 strokes of Taber abrasion tester

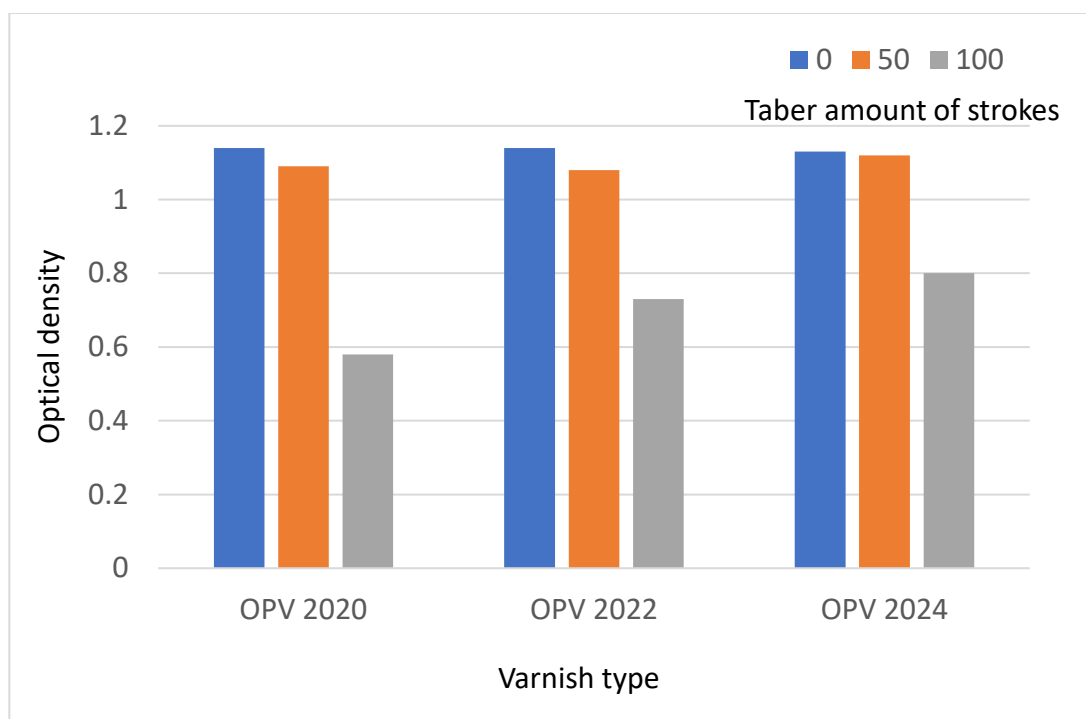


Figure 6: Optical density of labels varnished with three different chemistries with anilox 550LPI/3.1 BCM. Optical density was measured after printing (0), after 50 strokes of Taber abrasion tester (50), and after 100 strokes of Taber abrasion tester

The efficiency of individual varnishes was compared using the same anilox 550LPI/3.1 BCM. Figure 5 shows that the resin OPV 2024 provided the best protection, which is most obvious after 100 Taber abrasion strokes. The label had the highest optical density when protected with this varnish, followed by OPV 2022. Worst protection was observed with OPV 2020, where the optical density of the print after 100 Taber strokes was the lowest at the thinnest layer of the varnish. The chemical composition of OPV 2020 was as follows: Epoxy Acrylate, Oxybis (methyl-2,1-ethanediol) diacrylate, Diacrylate Ester, Benzophenone, and another proprietary photoinitiator. The OPV2022 had the same composition plus Polyurethane resin, which made it slightly more powerful than the OPV2020. The OPV 2024 also had the same components as OPV 2020, plus Acrylated Polysiloxanes, Pentaerythritol triacrylate esters, and Pentaerythritol tetraacrylate esters, which made this formulation the most powerful varnish.

Optical density loss was measured on black area of the label. In our testing approach, we did not attempt to distinguish between loose ink particles and rubbing of the ink. Using dE00 as a metric includes a maximization of how the color difference is observed, regardless of the hue of the color. We tried to map the density loss against the dE00-value, but it did not show any reasonable trend.

4. Conclusions

Three different designs of labels were flexo printed and later overprinted with different varnishes using three different resolution anilox rollers. As expected, the overprint varnish printed with the lowest resolution anilox produced the thickest protection layer and, thus, the least abrasion of the label design. When looking at different chemistries of overprint varnishes, varnish enriched with

polyurethane resin and varnish enriched with acrylated polysiloxanes and pentaerythritol components were more powerful than epoxy acrylate resin alone.

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