DOI 10.1515/secm-2012-0070 — Sci Eng Compos Mater 2013; 20(2): 141–145

Cem Aydemir*, Zafer Özomay, Arif Karademir and Emine Arman Kandırmaz

Effects of matte coating on the paper surface and print density

Abstract: In this work, standard laboratory printing applications with IGT (ISO 12647-2) were applied on uncoated and matte-coated papers using offset inks (DIN ISO 2846-1). Surface roughnesses of uncoated and coated sheets were recorded to be 195 and 13 ml/min, respectively. Air permanence values of uncoated and coated papers were found to be 5.6 and 0.103 μm/Pa·s, respectively. Changes in the print densities were recorded up to 48 h. Print density changes for uncoated and matte-coated papers were surprisingly found to be in similar paths (8% in the first 4 h), although significant differences between surface roughnesses were recorded. Furthermore, paper samples showed similar behaviors for the percent volume changes, where drop volume disappeared within 6 min. It is concluded that matte coating did not have any significant effects on print density change and drop volume change.

Keywords: IGT printability; paper coating; paper roughness; print density.

***Corresponding author: Cem Aydemir,** Department of Printing, Faculty of Technical Education, Marmara University, Goztepe Campus, 34722 Goztepe, Istanbul, Turkey, e-mail: cemaydemir@marmara.edu.tr
Zafer Özomay and Emine Arman Kandırmaz: Department of Printing, Faculty of Technical Education, Marmara University, Goztepe Campus, 34722 Goztepe, Istanbul, Turkey
Arif Karademir: Department of Forest Industry Engineering, Faculty of Forestry, Bursa Technical University, 16200 Merinos, Bursa, Turkey

1 Introduction

Printing has been the main process that used paper in the form of letters, pictures, drafts and so on since its invention. Some papers are specifically produced for printing; thus, they undergo many operations such as calendering, coating, and surface sizing as well as filler loading during production. Paper surface properties, smoothness, surface energy and porosity as well as sizing degree greatly affect the interactions between liquids and papers. Fiber properties such as coarseness, beating, filler loading, pressing, calendering and coating are some of the main factors that mostly affect the surface roughness and porosity of paper products. The diameters of pores and uniform distribution in the paper structure are also important for ink absorption [1, 2].

A liquid droplet touching a paper surface tends to both penetrate into the paper structure and spread over the surface. The extent of penetration or spreading depends on both the properties of the paper and liquids (ink) and environmental conditions like temperature, humidity and pressure. Inks can be classified into three main groups according to the carrier medium as solvent-based, oil-based and water-based. Depending on the nature of the interaction between the ink and the paper, some extra roughness (distortion) on the paper surface may be created to some extent in addition to the initial paper roughness. Lepoutre and Skowronski conducted a research on the relationships between ink penetration and surface roughness and concluded that ink penetration into paper causes stress relaxation, swelling and debonding [3–5]. Such changes on paper surfaces are more prevalent in the case of water-based inks [6, 7]. A physicochemical interaction between paper and printing ink greatly determines the spreading of wet ink, as well as setting and drying [8]. Interactions are purely physical in nature when solvent-based inks are used, but are quite complicated and complex in the case of water-based inks [8, 9]. Water in the ink itself interacts with all the ingredients of paper and leads to a distortion on the paper. The pH of water needs to be carefully controlled and kept over pH 9 [10]. Despite such problematic aspects of water-based inks, the use of water-based inks instead of solvent-based ones is still highly encouraged due to environmental and health concerns. Oil-based inks, compared to water-based inks, do not cause a great detrimental distortion on the paper surface and do not create a danger for health and the environment like solvent-based ones. Three basic mechanisms control ink behavior on paper surfaces. These mechanisms, namely, penetration, evaporation of fluid and swelling, were studied in detail by some researchers [1, 11–13].

Printing inks basically consist of a carrier medium such as water, solvent or oil, coloring ingredients, and pigments

Unauthenticated
Download Date | 1/23/20 8:25 PM

and may also contain binders. During printing, the carrier medium tends to get inside the paper through capillaries and voids between fibers/fillers and also into lumens of cellulosic fibers. Pigments, however, cannot travel so easily into the paper structure compared to the carrier, but stay on the surface. Pigment movements to the inner parts of the paper are improved by the help of paper porosity. The more porous the paper, the deeper the pigments move in. From the point of printing quality, pigments should actually stay on the paper surface and give a higher print density with a limited amount of ink. Papers absorbing inks as a whole with carrier and pigments directly increase the ink consumption and operating costs while giving a poor density profile. Some evaporation from the ink carrier also occurs [14, 15]. The time required for inks to settle, dry and hardened are important as far as economy is concerned.

Paper coating is applied to improve the surface properties of sheets and develop the quality of printing room operations. Coating color may contain a variety of ingredients depending on the coating purposes. The higher proportion of coating color normally consists of finely ground fillers such as calcium carbonate, kaolin and titanium dioxide [16, 17].

In this work, standard offset printing operations were performed on uncoated and coated sheets by means of an IGT testing device using an offset ink. Coating improved the surface smoothness of sheets and air resistance, but did not affect the print density of papers.

2 Materials and methods

Two different papers, uncoated and matte-coated, were used in these experiments. The base papers were made from bleached virgin printing-grade pulps. The brightness of the papers was in a similar range, whereas other properties, especially roughness and air permeability, varied considerably.

The papers were tested to determine the following properties: brightness (ISO 2470-2), gloss (Tappi 75; TAPPI T 480 om-92) and air permeability (ISO 5636/3).

Printing applications at 35-mm width were conducted on papers with an offset ink from Michael Huber Resista Ink Cyan series (DIN ISO 2846-1) (Münich, Germany). The IGT printing device was operated at a speed of 0.3 m/s and 350 N force according to ISO 12647-2 standard in a controlled atmosphere, where samples were also kept for at least 24 h at 23±1°C and 50±2% relative humidity before the printing. Print density measurements on printed papers were done with a Gretag Macbeth SpectraEye device adjusted at D50 illumination, 2° monitoring and 0/45 black area. Measurements were repeated at close intervals for a period of 2 days.

The sessile drop method is one of the most common methods for measuring the contact angle, which involves depositing a liquid drop on a solid surface and measuring the angle between the solid surface and the tangent to the drop profile at the drop edge. In this study, the time-dependent behavior of a sessile droplet of water was observed with an optical contact angle device (DataPhysics Instruments, Germany) using OCAH 230 software and apparatus. In this technique, a water droplet is placed on the paper with a computer-controlled syringe. The water droplet is illuminated by a halogen lamp with continuously adjustable intensity. The droplet is observed with a charge-coupled device video camera with a resolution of 752×582 pixels at a rate of up to 50 images per second. The camera is equipped with a power zoom of 0.7- to 4.5-fold magnification and within optical distortion of <0.05%. This fully automated device is capable of measuring the volume of a droplet by determining the profile and the baseline of the droplet. The profile of the droplet is approximated by the built-in software of the device as a circle or an ellipse. The profiles are determined by marking at least three points on the contour of the droplet for a circle, and at least five points for an ellipse. The profiles are also used to measure the contact angle when the appropriate option is chosen for this purpose [2].

3 Results and discussion

3.1 Paper surface properties

Gloss, surface roughness and air permanence values of matte-coated paper were greatly different from those of uncoated sheet (Table 1). The surface structure of uncoated paper is made up of only cellulose fibers and some amount of fillers that were internally added. Therefore, the surface roughness of such paper is dependent on both the quality of fibers on the surface and the formation quality of sheets. Fiber length, flexibility, freeness level and conformability are some factors that determine how well a mass of fibers would form a composite structure. Beaten and shorter fibers give sheets with a smoother surface, whereas long and rigid fibers increase surface roughness [18]. Filler added during stock preparation is distributed in a paper matrix in different proportions. On the Fourdrinier machine, for example, the amounts of filler are normally higher on the top side of the sheet than

Unauthenticated
Download Date | 1/23/20 8:25 PM

Features	Standard	Matte-coated paper	Uncoated white paper
Grammage (g/m^2)	ISO 536	115.0	120.0
Thickness (μm)	TAPPI T 411	107	107
Bulk (cm^3/g)	ISO 534:1995	0.82	1.25
Whiteness (CIE D65/10) (%)	ISO 11475	122	146
Brightness (D65/10) (%)	ISO 2470-2	99	82.3
Opacity (D65/10) (%)	ISO 2471	94.5	96.5
Gloss (TAPPI 75) (%)	T480 om-92	30	6
Air permanence (Bendtsen) (μm/Pa·s)	ISO 5636/3	0.103	5.610

Table 1 Some properties of substrate papers used.

on the web side. During sheet formation on the wet end of a paper machine, some fiber debris, fines and fillers are inevitably lost in greater amount from the web side than the top side. The homogeneous distribution of retained fillers inside the paper structure and surfaces are also important. It is desired that fillers would fill gaps, voids and valleys between fibers and make the paper surface smoother [19–21]. In addition, both wet and dry pressing programs, drying regime and calendering have great effects on the surface properties of papers.

The coating operation transfers a thin and uniform layer of filler barriers on a paper surface as seen in Figure 1 [22]. The coating layer consists of a variety of components at different proportions along with fillers such as a dispersant, binder, optical brightener, lubricant and so on [16, 17]. The parameters of coating colors, application types (blade coating, roll coatings, etc.) and base paper properties determine the quality of the coating operation and end products [16, 23]. It is seen here that coating greatly changed some properties of sheets. Surface roughnesses of uncoated and coated sheets were found to be 195 and 13 ml/min, respectively. Air permanence values of uncoated and coated papers were found to be 5.6 and 0.103 μm/Pa·s, respectively (Table 1). Results indicated that the coating operation had created a firmly packed layer on the paper surfaces that were smoother and acted as a barrier to air passage in the paper structure, leading to a higher air resistance.

Fourier transform infrared spectra of the tested sheets were also taken (Figure 2). The peaks appearing at 1794.46, 1385.60, 870.60 and 712.17 cm^{-1} were reported to be the indication of calcium carbonate fillers [24, 25]. Peaks visible at around 1385 and 872 cm^{-1} on attenuated total reflectance (ATR) spectra of uncoated sheets were

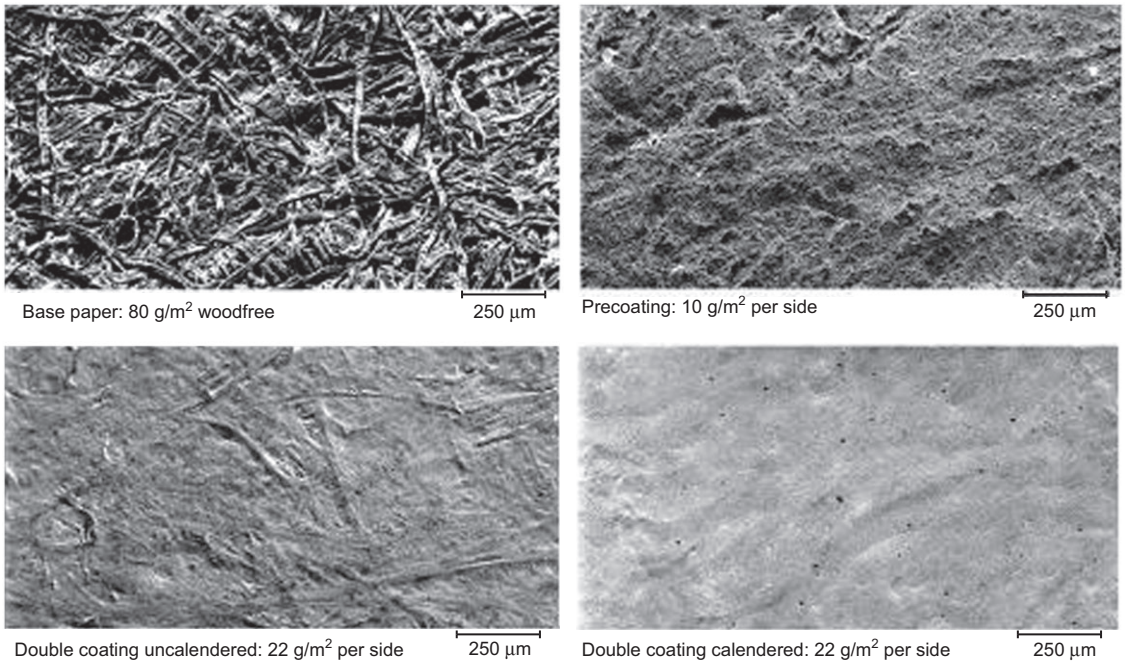


Figure 1 Surface images of uncoated and differently coated papers [17].

Unauthenticated
Download Date | 1/23/20 8:25 PM

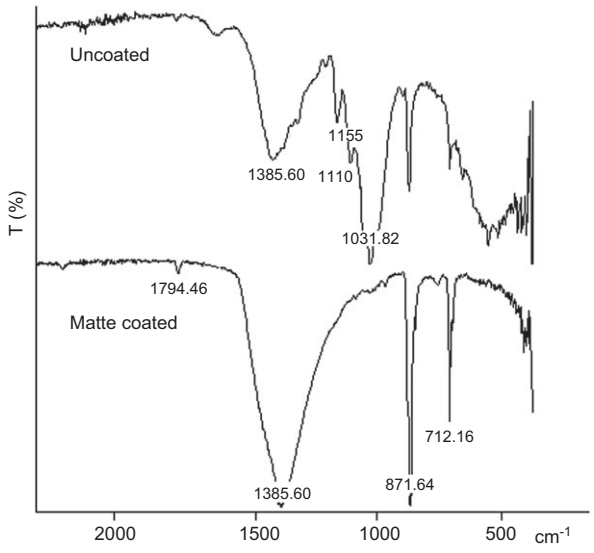


Figure 2 ATR spectrums of uncoated and matte-coated paper surfaces.

attributed to internally added fillers, calcium carbonate. It is obvious that peaks referring to cellulose fibers were missing in the ATR spectra taken from coated papers, where peaks attributed to calcium carbonate are dominant, which proves full surface coverage. The peaks and corresponding components are listed in Table 2 [24, 25].

3.2 Printing and print quality

Oil-based printing ink meeting the DIN ISO 2846-1 and 12647-2 standards was used in the operation. The properties of the ink are given in Table 3.

The printed papers were tested to find out the change in print density over time, and results are plotted in Figure 3. It was found that print density changes on both papers were almost the same. It means that both papers were actually absorbing printing inks at the same velocity and

Wave number (cm^{-1})	Assignment
1795	Peaks from $CaCO_3$
1385	Peaks from $CaCO_3$
1155	Antisymmetric bridge C–OR–stretching (cellulose)
1110	Anhydroglucose ring (cellulose)
1030	C–OR stretching (cellulose)
872	Peaks indicating $CaCO_3$
712	Peaks indicating $CaCO_3$

Table 2 ATR peaks taken from surfaces of uncoated and coated papers.

Parameters	Values
Boiling point	250°C
Flash point	>100°C
Ignition point	200°C
Vapor pressure (at 20°C)	<0.1 hPa
Density (at 20°C)	1.088 g/cm^3
Solvent content	Organic solvents <0.5%, water <0.5%

Table 3 The properties of ink used.

leaving the same amounts of pigments over the surface; hence, similar degrees of print density changes were created. The result needs further explanation, as surface roughness and air permeability of both papers were significantly different. Porous sheets are expected to take more pigments to the inner part of the structure with solvent depending on the pore diameters and morphologies. Therefore, uncoated paper, having higher air permeability, was expected to take more ink in a shorter time than coated paper. Coated paper, however, having a smoother surface and lower air permeability, should have actually absorbed less ink at a very slow speed. Results, however, revealed that interactions between inks and both papers were similar. It simply says that the coating layer had a high ink-absorbent quality. The total surface area on the coating layer over paper must be significantly bigger than the area of the uncoated paper surface. Therefore, fillers in the coated layers were believed to take a great amount of ink.

The papers were also analyzed by the sessile drop method to find out the behavior of a water droplet on sheets because density change tests were actually revealing the interactions between papers and oil-based printing inks. It was found that water droplets on both uncoated and

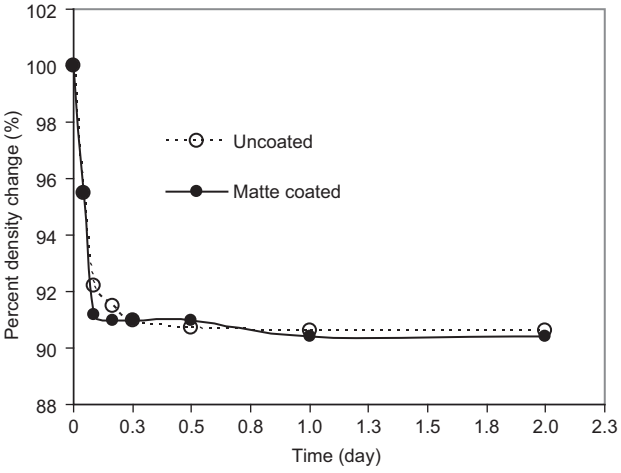


Figure 3 Changes in print density of printed papers over time.

Unauthenticated
Download Date | 1/23/20 8:25 PM

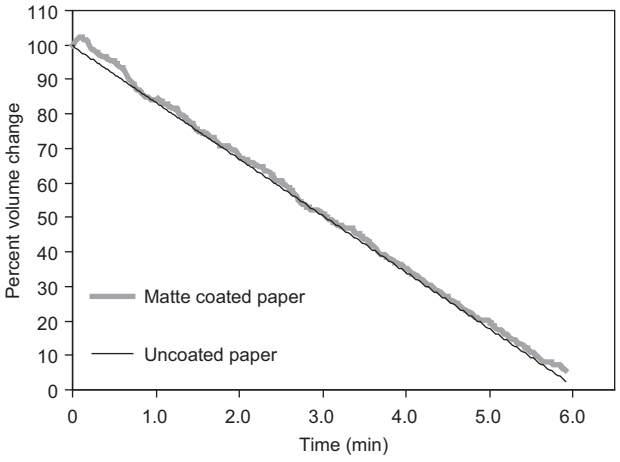


Figure 4 Volume changes of a water drop on uncoated and coated paper surfaces over time.

coated papers behaved in a very similar manner (Figure 4). The water droplet disappeared on sheets within 6 min. This shows that matte coating would not change the printing operation if water-based ink is to be used.

4 Conclusion

Matte coating significantly increased the surface smoothness from 195 to 13 ml/min and the air resistance of paper from 5.6 to 0.103 μm/Pa·s; similar effects on print density change and drop volume change were not noted. Eight percent of changes were recorded in the print density of both samples within 4 h after printing. Water droplets were fully absorbed by both samples within 6 min at a similar rate. The absorption quality of the coating layers due to the greater surface areas of fine fillers was responsible for ink and water absorption. This showed that matte coating would not affect the printing process when oil-based inks are used. Then, the main outcome of matte coating will be the surface smoothness and air resistance. The relationship between air permeability and ink absorption needs to be further studied, as air permeability and surface roughness of sheets were significantly reduced here without any change in the print density of the papers tested.

Received August 1, 2012; accepted October 23, 2012; previously published online November 23, 2012

References

[1] Navaz HK, Markicevic B, Zand AR, Sikorski Y, Chan E, Sanders M, D'Onofrio TG. *J. Coll. Inter. Sci.* 2008, 325, 440–446.
[2] Aydemir C. *Int. J. Polym. Mater.* 2010, 59, 387–397.
[3] Lepoutre P, Skowronski J, Bichard W. Tappi Coating Conference. TAPPI Press: Washington, 1986, p. 113.
[4] Skowronski J, Lepoutre P. *Tappi J.* 1985, 68, 98–102.
[5] Lehtinen E. *Pigment Coating and Surface Sizing of Paper.* Finish Paper Engineers Assoc., TAPPI Press: Atlanta, 2000, p. 34.
[6] Brielles N, Chantraine F, Viana M, Chulia D, Barnlard P, Rubinstein G, Lequeux F, Mondain-Monval O. *J. Coll. Inter. Sci.* 2008, 328, 344–352.
[7] Wang J, Thom V, Hollas M, Johannsmann D. *J. Membr. Sci.* 2008, 318, 280–287.
[8] Aydemir C, Karademir A, Imamoglu S. *Int. J. Polym. Mater.* 2010, 59, 891–901.
[9] Thompson B. *Printing Materials: Science and Technology*, 2nd ed., Pira: London, UK, 1998.
[10] White PG. *Cylinder Requirements for Water-Based Inks*. Southern Graphic Systems, Louisville, 1998, p. 19.
[11] Ramon G, Oron A. *J. Coll. Inter. Sci.* 2008, 327, 145–151.
[12] Senden TJ, Knackstedt MA, Lyne B. *Nord. Pulp Pap. Res. J.* 2000, 15, 554–563.
[13] Denesuk M, Smith GL, Zelinski BJJ, Uhlman DR. *J. Coll. Inter. Sci.* 1993, 158, 114–120.
[14] Karppinen T, Kassamakov I, Aaltonen J, Pajari H, Hæggström E. *Eur. Phys. J. Appl. Phys.* 2005, 32, 65–71.
[15] Marmur A, Cohen RD. *J. Coll. Inter. Sci.* 1997, 189, 299–304.
[16] Stranger K. *Surface Application of Paper Chemicals*. Springer: London, 1997.
[17] Coating Color Formulation in Papermaking Chemistry & Technology. Available at http://chempatec-auhorn.com/coating/index.html. Accessed 04 December 2009.
[18] I'Anson SJ, Karademir A, Sampson WW. *APPITA J.* 2006, 59, 297–301.
[19] Karademir A. *Turk. J. Agric. For.* 2002, 26, 253–260.
[20] Karademir A, Chew YS, Hoyland RW, Xiao H. *Can. J. Chem. Eng.* 2005, 83, 603–606.
[21] Karademir A, Hoyland D, Wiseman N, Xiao H. *APPITA J.* 2004, 57, 116–120.
[22] Paper Coating in Papermaking Chemistry & Technology. Available at http://chempatec-auhorn.com/coating/index.html. Accessed 03 December 2009.
[23] Imamoglu S, Karademir A. *APPITA J.* 2006, 59, 218–224.
[24] Jackson KDO. *Internet J. Vib. Spectrosc.* 1998, 2, 3.
[25] Shimadzu Application News. Available at http://www2.shimadzu.com/applications/ftir/a395.pdf. Accessed 04 December 2009.

Unauthenticated
Download Date | 1/23/20 8:25 PM