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The Effect of Binder Type on the Physical Properties of Coated Paper

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ABSTRACT
Paper is a thin material used for drawing, printing or packaging. Generally, it is obtained as a result of pressing the cellulose pulp obtained from the wood fibers. Paper is the most important material in printing and packaging material. Nowadays, as a result of technological developments and the growth of the advertising industry, the expectations from the paper have increased. For this reason, paper coating process is done for having some physical properties. The main purpose of paper coating process is to cover the paper fibers by filling a thin film layer of pigment, binder and some additives onto the base paper or cardboard, to fill in the gaps between them and to obtain a smoother surface. Paper has to have better printability parameters in the printing industry. We can explain these parameters as surface smoothness, roughness, brightness, opacity and whiteness. Most commonly pigments used in paper coating are kaolin, clay and titanium dioxide and on the other hand binders are latex, starch and polyvinyl alcohol types. It requires using paper having different physical properties because of development in printing techniques, ink type and ink transfer method. In this study, the coating formulations were prepared using a pigment and two binders and coated on the base paper. The effect of the binder on the physical properties of the paper was examined and commented on. Coating used polyvinyl alcohol as a binder has a higher brightness value, whereas coating with starch has a higher opacity. Also, the coated papers were calendered and changing of physical properties after calendering process is shared.
Keywords: Binder, Brightness, Coating, Opacity, Paper, Physical Properties

Bağlayıcı Tipinin Kaplanmış Kağıtların Fiziksel Özelliklerine Etkisi

ÖZ
Kâğıt, çizim, baskı veya ambalaj amacıyla kullanılan ince malzemedir. Genel olarak ağaç liflerinden elde edilen selüloz hamurunun preslenmesiyle oluşturulan levhaların kurutulması sonucunda elde edilir. Günümüzde kâğıt, basım ve ambalaj sektörünün en önemli malzemesidir. Teknolojik gelişmeler, reklam sektörünün gelişimi ve bunun sonucunda tüketici beklentilerinin artmasıyla kâğıttan da beklentiler artmıştır. Bu yüzden kâğıda birtakım özellikler kazandırmak için kaplama işlemi yapılır. Bu işlemin temel amacı, ham kâğıdın üzerine pigment, bağlayıcı ve bazı katkı maddelerinden oluşan ince bir film tabakasını kaplayarak kâğıt liflerinin üzerini örtmek, aralardaki boşlukları doldurmak ve bu sayede daha düzgün bir yüzey elde etmektir. Basım sektörü için kâğıdın basılabilirlik parametrelerinin iyi olması gerekmektedir. Bu parametreleri genel olarak yüzeyin düzgünlüğü, pürüzsüzlüğü, parlaklığı, opaklığı ve beyazlığı olarak sayabiliriz. Kâğıt üzerine yapılan kaplamalar için yaygın olarak kullanılan pigmentler kaolin, kalsiyum karbonat, titanyum dioksit ve bağlayıcı olarak ta polivinil alkol türleri, nişasta ve lateks maddeleri sayabiliriz. Basım tekniklerindeki gelişmeler, mürekkebin yapısı ve transfer şekli farklı fiziksel özelliklerde kağıtları kullanmayı gerektirmektedir. Yapılan çalışmada iki farklı bağlayıcı ile tek bir pigment kullanılarak kaplama formülasyonu hazırlanmış ve ham kâğıt üzerine kaplanmıştır. Bağlayıcının kâğıdın fiziksel özelliklerine etkisi incelenmiş ve yorumlar yapılmıştır. Bağlayıcı olarak polivinil alkol kullanılan kaplamanın parlaklık değeri daha yüksek çıkarken, bağlayıcısı nişasta olan kaplamanın ise opaklığı daha yüksek elde edilmektedir. Ayrıca kaplanmış kağıtların kalenderleme işlemleri de yapılarak kalender işlemi sonrasındaki değişimler de paylaşılmıştır.
Anahtar Kelimeler: Bağlayıcı, Fiziksel Özellikler, Kâğıt, Kaplama, Opaklık, Parlaklık

INTRODUCTION

Paper is a thin material that can be printed on or used for packaging purposes. Generally, it can be made from cellulose from wood fibers. Coating applications can be done on paper or paperboard to add them more specialty or improve their characteristics. Coated paper is paper which has been coated by a pigment, binder and some additives to obtain surface gloss, smoothness or reduced ink absorbency. The paper is called base paper before the coating application. After coating application, it is called coated paper. Coating is a compound and pigment is its leading component (80 to 95% by weight and around 70/100 by volume of the dry coating). Coating can be composed of one or more kinds of pigments [1, 2]. In general calcium carbonate,

precipitated calcium carbonate (PCC), ground calcium carbonate (GCC), kaolin (clay), talc, gypsum, plastic pigments, alumina trihydrate, titanium dioxide, silica and barium sulfate and such pigments are used in coating formulations used for various papers [3, 4]. Different demands of customers have increased the necessity for different pigments to increase the surface characteristics, gloss, cost efficiency and to reduce environmental impacts [5, 6]. Expectations from the paper coating pigments can be seen Table 1.
In general, the paperweight of pigment-coated paper consists of 70% base paper, which also comprises 90% of the volume. Base paper is simply divided into two types; mechanical pulp-dominated paper and chemical (wood-free) pulp-dominated paper [7, 8]. Nowadays, coated mechanical paper mostly refers to LWC (lightweight coated) paper. It is seldom the case that a mechanical base paper is applied to any digital paper. Most coated paper is 90% chemical pulp-dominated base paper, which has no wood and whose mechanical pulp fraction is less than 10% [9].

Table 1. Essential Pigment Properties in Paper Coating

Category	Required Properties
Chemical & Physical	Chemically stable Mix easily with water Low solubility in water Good compatibility with other components Appropriate particle size and shape distribution Purity Low density Less abrasive
Optical	Good brightness Good opacity
Rheological	Good flow properties Small binder demand
Economic	Low cost

Binders are essential to bind the pigment particles to the base paper and to partly fill the voids between the pigments in the coating structure (Figure 1). It functions like glue, and affects rheological properties. Binder accounts for only about 5-20 wt. % of dry coating, but covers the most part of coating formulation cost. The most common binders are presented in Figure 2. The amount of binder is ordered by paper end use. For instance, offset printing paper requires high binder content, because the high tack of offset ink, while rotogravure needs a lower binder content [10]. The ideal binder should have these properties:

- Good binding capacity
- Good water retention
- Water soluble
- Compatibility with other coating components
- Good optical properties
- Good mechanical properties
- Chemical and mechanical stability and durability
- Nontoxic,
- Odorless
- Low foaming characteristics
- Inexpensive

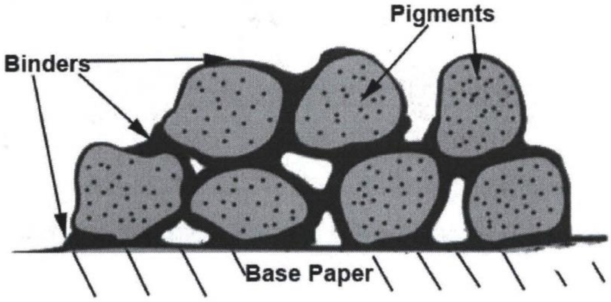

Figure1. Function of Binders in the Coating Layers

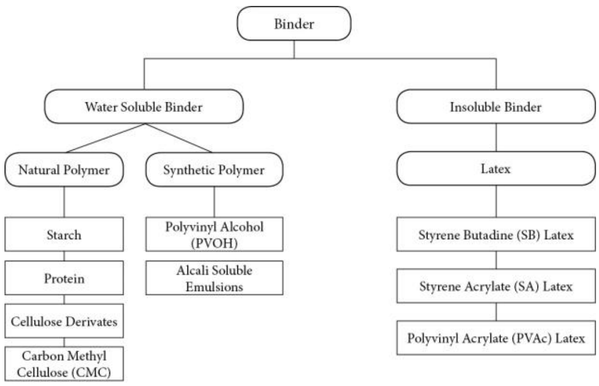

Figure2. Classification of Binders [11]

Starch is the most useful binder in paper coating due to its plenty supply and low price. Starch is a carbohydrate synthesized in corn, tapioca, potato, and other plants by polymerization of dextrose units. Starch is normally supplied as a white, grainy powder by packs and containers; liquid starch supply is seen in specific fields, such as tissue paper. Starch is not soluble in cold water, because of the polymerized structure and hydrogen bonding between adjacent chains. However, when this aqueous suspension is heated, water will penetrate into the starch and swell, producing a "gelatinized" solution or paste, depending on its concentration [12, 13].
PVOH is a white granular synthetic polymer, which can be dissolved in water, and is widely recognized as one of the strongest binders available in the paper industry [14]. The PVOH manufacturing process starts with the vinyl acetate monomer polymerization to polyvinyl acetate via a free radical reaction. Polyvinyl acetate is then hydrolyzed to PVOH via a base-catalyzed saponification reaction [15].

MATERIAL and METHOD

In the study, coating formulations were prepared using two different binder PVOH, cationic starch and one pigment kaolin clay (Table 2) and coated on the base

paper. The effect of the binder on the physical properties of the paper was studied. In addition, the coated papers were also made calendering and the changes after the calendering process were shared.
Base paper is selected for the experiments and its physical and optical properties are characterized. The standards used for the testings are as below:

- TAPPI T460 om-11 for Porosity measurements,
- TAPPI T538 om-08 for Roughness measurements,
- TAPPI T411 om-10 for Thickness measurements,
- TAPPI T452 om-08 for Brightness measurements,
- TAPPI T480 om-09 for Gloss measurements,
- TAPPI T410 om-13 for Grammage measurements,
- TAPPI T527 om-13 for L*a*b* values measurements,
- TAPPI T425 om-11 for Opacity measurements.

Table 2. Coating Formulations and Ingredients

Ingredients	Dry Parts Added		Solids
Kaolin	100		70%
PVOH	10		40%
Cationic Starch		10	40%
Dispersant	.2	.2	40%
Thickener	.8	.8	30%

Arrow 1750 Three-Blade Mixer is used to mix and then Cowles CM-100 Lab Dissolver is (Figure 3) used to disperse materials. The target solids of the coatings are 55% and are measured on the CEM Smart Solids Analyzer (Figure 4).

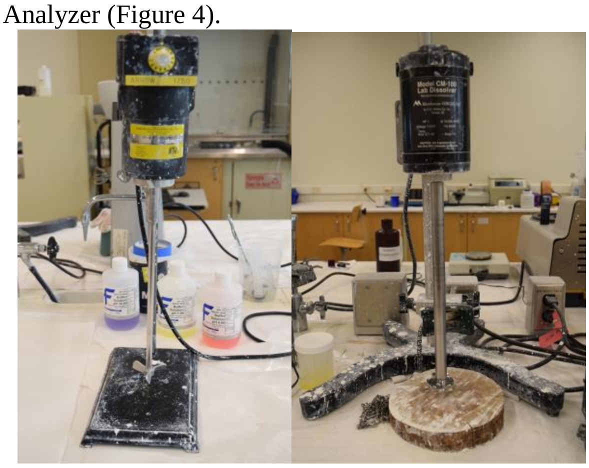

Figure 3: Arrow 1750 Three-Blade Mixer and Cowles CM-100 Lab Dissolver

Figure4. CEM Smart Solids Analyzer

The solids of the coatings are measured after all adjustments to pH and viscosity are done. The pH of coating is adjusted using solution of ammonium hydroxide solution (NH_4OH) to increase and sodium hydroxide (NaOH) to decrease the pH to a target of 8.5-9.
The viscosities of the coatings are measured at room temperature using a Brookfield Viscometer (Figure 5), #4 spindles, at 100 rpm. The adjustments of the viscosity are made with a 3% solution of carboxymethylated cellulose (CMC) solution (by weight), until a Brookfield viscosity of approximately 1,200 cps is achieved.

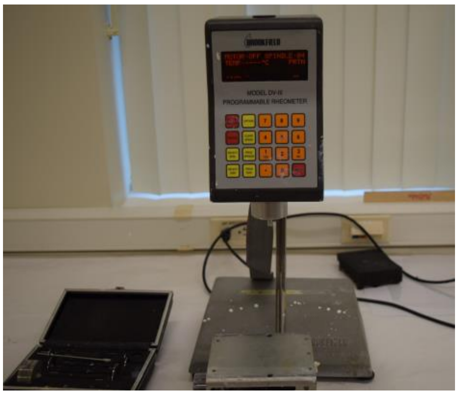

Figure 5: Brookfield Viscometer

Technidyne Brightimeter Micro S-5 (Figure 6) is used to measure brightness, CIELAB, whiteness and yellowness for coated papers. Technidyne Opacity Tester is used to measure opacity for all papers (Figure 7). Technidyne Profile Plus is used to measure roughness, porosity, thickness, and 75° gloss for all papers (Figure 8).

Figure6. Technidyne Brightimeter Micro S-5

Figure7. Technidyne Opacity Tester

Figure8. Technidyne Profile Plus

RESULT and DISCUSSION

The physical and optical properties of the base paper used in the study were given in Table 3. The optical and physical properties of the coated and calendered papers were given in Table 4.

Table 3. Physical and Optical Properties of Base Paper

Base Paper		Unit	Ave.	High	Low	Std. Dev.
Brightness		%	88.43	88.73	88.13	0.19
Opacity		%	88.21	90.20	87.50	0.83
GSM		g/m^2	54.59	55.65	53.31	0.75
Roughness		(μm)	194.0	205.80	182.4	7.89
Porosity		(mL/min)	9.68	10.97	8.37	0.82
Thickness		(μm)	81	86	77	2
Top Gloss			6.10	7.00	5.30	0.55
MD		75° (%)	5.94	6.90	5.10	0.59
CD			6.21	7.00	5.50	0.56
	L*		97.10	97.26	97.02	0.09
CIE	a*		0.22	0.30	-0.03	0.06
	b*		3.63	3.68	3.22	0.03
CIE Wh			77.87	78.60	77.12	0.42
ASTM Yel			6.17	6.43	5.05	0.40

Table 4. Physical and Optical Properties of Coated and Calendered Papers

		Kaolin + C. Starch Coated	Kaolin + C. Starch Calendered	Kaolin + PVOH Coated	Kaolin + PVOH Calendered
Brightness		87.17	88.15	86.67	87.13
Opacity		92.17	92.43	90.81	89.98
GSM		59.39	59.38	59.25	59.25
Roughness		166.06	90.52	165,18	93.11
Porosity		325.27	380.78	245,18	398.19
Thickness		107	79	105	80
Top Gloss		14.1	41.5	13.1	35.0
MD		13.7	40.3	13.2	35.0
CD		14.5	41.9	12.1	35.1
	L*	96.55	96.64	97.39	96.94
CIE	a*	0.36	0.42	0.42	0.48
	b*	3.68	3.23	3.19	3.44
CIE Wh		74.63	73.10	78.35	77.86
ASTM Yel		7.25	7.39	6.09	6.13

The highest brightness and opacity values are onto cationic starch coatings. Also, the surface roughness and porosity are better onto cationic starch coatings.
The grammage values were almost at the same level. This means that the coatings quantities were set correctly. Thickness values are high on cationic starch coatings. Because cationic starch densities are higher than PVOH. So, thicker coatings can be obtained when cationic starch used according to PVOH.
Gloss values are higher onto the cationic starch coatings than PVOH coatings. Whiteness values are higher on the coatings used PVOH and yellowness values are higher on the coatings used cationic starch.

The binder type and amount should be determined according to the end use of the paper or print product. For example, offset lithography paper needs high binder content, because the high tack of offset ink, while flexography needs lower binder content.

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