USING POLYVINYL ALCOHOL IN INK-JET PRINTING PAPER

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THE PERFORMANCE CHARACTERISTICS OF POLYVINYL ALCOHOL HAVE MADE IT A PREFERRED POLYMER FOR USE IN PIGMENTED INK-JET COATING SYSTEMS.

ADVANCES IN INK-JET PRINTING TECHNOLOGY HAVE resulted in a new generation of ink-jet printers that can print faster at wider paper widths and produce four-color images close to photographic quality. Ink-jet printing papers must be tailored to these changes through quick ink absorption, minimizing ink bleed and ink wicking while retaining favorable ink optical density values. To meet these demands, many papermakers are turning to pigmented size press and special coatings formulations. Polyvinyl alcohol (PVOH) is the binder of choice for pigmented ink-jet papers due to excellent binding strength, affinity for water, and its ability to boost optical brightener performance in high brightness ink-jet papers.

BACKGROUND OF PVOH CHEMISTRY

Polyvinyl alcohol is available as a white granular solid that can be solubilized in hot water. It is manufactured by first producing polyvinyl acetate from vinyl acetate monomer (VAM) via a free radical polymerization. The polyvinyl acetate is in turn hydrolyzed to PVOH via a base-catalyzed saponification reaction. The molecular weight of PVOH is controlled through the polymerization step and generally is expressed in terms of a 4% solution viscosity. The viscosities are classified as ultra-low, low, medium, and high. The degree to which the polyvinyl acetate is converted to polyvinyl alcohol is referred to as the percent hydrolysis and is controlled during the saponification reactions. The percent hydrolysis is commonly denoted as super (99.3%+ conversion of vinyl acetate to vinyl alcohol), fully (98.0–98.8%), intermediate (95.5–97.5%), and partially (87.0–89.0%) hydrolyzed.

With regard to ink-jet coatings, the molecular weight of PVOH primarily controls the binding power for pigment adhesion and determines coating rheology. The percent hydrolysis also contributes to rheology but, in addition, plays a role in printability and optical density.

PVOH FOR PIGMENTED INK-JET SIZE PRESS APPLICATIONS

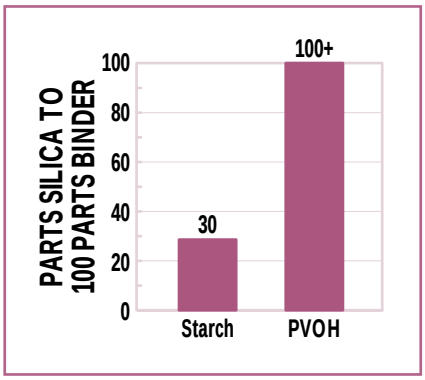
Either a fully hydrolyzed (98.0–98.8% hydrolysis), low molecular weight grade, or a fully hydrolyzed, medium molecular weight grade of PVOH is recommended for size press applications of silica pigmented formulations. Both grades offer excellent binding strength for the silica pigment, and they provide good monochrome and color optical density as compared with conventional size press starch. Ink dry times are reduced with the addition of the silica in comparison with straight PVOH. The following information highlights these attributes.

Binding power

PVOH is widely recognized as one of the strongest binders available in the paper industry and, depending on the PVOH molecular weight, can be three to four times as strong as starch. Its use permits significantly reduced binder levels in size press formulations and maximum utilization of the silica's high absorption capabilities without dusting or linting problems, as seen in **Fig. 1.**

Sizing and optical density

The extent to which a paper is internally sized, or the combination of its internal and surface sizing, may have a significant impact on print optical density. In a slack-sized base sheet, PVOH can provide a boost to black and composite black optical print density compared with starch. The addition of silica pigment to the formulation may decrease black print density in light coat-weight treated papers, but it will significantly enhance other properties. Size press additives can be used to minimize this decrease in black print density when incorporating silica pigments.



1. Maximum silica loading prior to dusting

Ingredient	Dry parts
Silica	100
PVOH	50–200
Solids	8–15% for low MW 5–10% for medium MW
Coat weights	2–5 g/m²/side

I. Size press formulation

PVOH grade hydrolysis %, molecular weight	16% solids	13% solids	10% solids
99.3% hydrolysis, medium molecular weight	12,400 CPS (5)	510 CPS (3)	75 CPS (3)
96% hydrolysis, medium molecular weight	8180 CPS (5)	235 CPS (3)	50 CPS (3)
88% hydrolysis, medium molecular weight	4800 CPS (4)	122 CPS (3)	35 CPS (3)
98.4 hydrolysis, low molecular weight	4120 CPS (4)	105 CPS (3)	>50 CPS (3)

II. Brookfield viscosity of PVOH/ppt silica coatings; 100 parts silica/40 parts PVOH; Brookfield RV, 20 rpm, spindle as indicated in parentheses.

Ingredient	Dry parts
Silica	100
PVOH	30–50 (medium MW) 40–60 (low MW)
Defoamer*	0.05–0.1
Solids	15–30%
Viscosity	200–600 CPS (Air knife) 200–6000 CPS (Rod/blade)
Coat weight	8–12 g/m²/side

*Foammaster VF from Henkel Corp. and Antifoam 116 FG from Harcross Chemical are recommended defoamers.

III. Suggested coating formulation

Dry time

PVOH surface sizing without silica pigment addition may increase ink dry time undesirably in the same manner as moderate to high levels of internal sizing. Utilization of silica decreases ink dry time for a fully hydrolyzed size press treated sheet.

Starting size press formulations

A fully hydrolyzed, low molecular weight PVOH is the recommended binder for high size press solids and relatively low silica loading levels. A fully hydrolyzed, medium molecular weight PVOH is recommended for lower size press solids and greater silica loading levels. The starting formulation shown in **Table I** is recommended for a typical puddle size press application.

PVOH FOR COATING APPLICATIONS

PVOH provides excellent binding strength and improved ink-jet print quality versus typical latex binders used in other pigmented coating applications. Formulations of PVOH and silica pigment will, however, create a fairly viscous coating at relatively low solids. The viscosity that is developed is dependent upon the desired coating solids, the pigment-to-binder ratio and the grade of PVOH chosen as a binder.

PVOH vs. latex binders

Coating formulations utilizing typical latex binders with silica pigment produce ink-jet print images that are mottled, low in ink density, and have poor ink bleed control. These undesirable results may be due in part to the surfactants used to stabilize the latex particles. These surfactants may interfere with the wetting properties of the ink-jet inks. PVOH is naturally hydrophilic and can quickly absorb water-based ink, helping to prevent wicking and bleed. In particular, partially hydrolyzed grades of PVOH provide the best ink-jet printability in terms of ink optical density and dry time when used with silica pigments. This is due to the more open coating structure provided by the partially hydrolyzed grades.

Viscosity/rheology vs. solids

Due to hydrogen bonding between the PVOH hydroxyl groups and the silanol groups on the silica pigment, the final viscosity of PVOH/silica coatings increases sharply with small increases in solids. This phenomenon maximizes solids at 25–30%, depending on the grade of

PVOH, the pigment-to-binder ratio, and the type of silica pigment used in the formulation.

Partially hydrolyzed low/medium molecular weight grades allow for the highest level of coating solids. Incorporation of pigments other than silica could reduce the overall coating viscosity, thus allowing for a greater coating solids level versus an all-silica pigment coating.

Table II illustrates the Brookfield viscosity of a 100 parts silica/40 parts PVOH coating where hydrolysis and molecular weight of the PVOH are compared.

Binding power of PVOH

A binder level of 40–50 parts per 100 parts silica pigment generally will be required for the lower molecular weight grades to prevent dusting of most silica grades from the sheet surface. Medium molecular weight grades of PVOH will permit a binder-to-silica pigment ratio of 30–40 parts to 100 parts, respectively. Actual binder-to-pigment ratios will have to be tailored for a given base sheet and coating method. The type of silica, the surface area of the particle agglomerate, and the oil absorption capability of the silica also play a role in the PVOH binding efficiency.

Additives

PVOH possesses a nonionic charge and, therefore, is compatible with most coating additives, including all types of cationic additives and surface sizing agents.

Recommended grades and starting formulations

Partially hydrolyzed (87–89%), ultra low/low/medium molecular weight grades are recommended for coating applications. A recommended starting formulation for ink-jet coatings is shown in **Table III**. **TJ**

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