Metered size presses: starch runnability and paper properties

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Runnability of the metered size press is affected by both chemical modification and the molecular weight of the starch.

Improving printability is the major reason for applying starch to the surface of paper. Starch is traditionally applied to paper by drawing the dried web through a pond or puddle of starch solution at the ingoing nip of two rubber rolls. The pressure exerted on these rolls limits the amount of starch that will pass through the size-press nip with the web. Pond instabilities and high sheet moistures cause an excessive number of web breaks as paper machine speeds approach 3280 ft/min (1000 m/min) (*1*).

Metered size-press technology has eliminated this pond and significantly reduced web breaks when speeds approach and exceed the 3280-ft/min (1000 m/min) threshold. A metered size press utilizes pressurized application heads to apply a thin film of starch solution to the rubber size-press rolls. The films are subsequently transferred to the paper web as the paper and film pass through the size-press nip. This thin-film technique permits operation of the size press at higher starch solids, which reduces the after-size-press drying load. It provides a method of accurately controlling the amount of starch deposited on the paper which is independent of solution solids, machine speed, or web absorbency, and it reduces or eliminates web breaks caused by hydrostatic pressures and pond instability.

This paper describes results from trials outlined in **Table I** utilizing a blade-metered size press. Two basic questions were asked. First, what roles do starch modifications and solution viscosities play on the runnability of a blade-metered size press? Second, what are the effects on paper properties of starches applied in a thin film by the blade-metered size press?

Runnability

A uniform film of 10% solids starch approximately 0.05 mm thick must be applied to the surface of the rubber size-press rolls to give a starch film of 5 g/m^2 (a starch pickup of 122 lb/ton). At this low film thickness, poor wetting of the rubber rolls becomes a potentially disastrous phenomenon. Although of great concern when planning the first trial, in actual practice poor wetting of the rolls was not encountered over the ranges of viscosities, molecular weights, or chemical modifications of the starches evaluated (**Table II**).

Although solution viscosity, molecular weight, and chemical modifications of the starch did not play significant roles in the wettability of the size-press rolls, they did influence the operation of the blade-metered size press.

Worldwide, pearl starch is the most commonly used starch on a conventional size press. The pearl starch is degraded in the paper mill to reduce its solution viscosity into the optimum operating range for a given paper grade and equipment used. Degradation is usually performed by thermal sheering, acid or ammonium persulfate hydrolysis, or enzyme conversion. Once the starch is in solution, heat and agitation prevent retrogradation or insolubilization of the hydrated starch (*2*). On a conventional flooded-nip size press, heat and turbulence also prevent retrogradation.

Retrogradation, however, can occur on the size-press rolls in a metered size-press configuration under certain conditions. At normal operating temperatures of 140°F (60°C), the vapor pressure of a starch solution is 150 torr (20 kPa), a strong driving force for evaporation of the water.

Although these conditions are common to the starch solutions in both a conventional size press and a metered size press, the surface area of the air–liquid interface is at least an order of magnitude larger for the metered size press than for the flooded-nip size press. There is rapid evaporation of water from the film at this vapor pressure with an extremely thin film spread over a large surface area. A combination of the film increasing in solids and simultaneously cooling because of the evaporation causes rapid buildup of the film viscosity or retrogradation or both. This phenomenon limits pearl starch's molecular weight and solution solids to a finished solution viscosity

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I. Mill trials reported on in this paper

Trial 1, February 1990	*Trial 2, August 1990*
Base paper	
75 g/m²	82 g/m²
France	United States
Alkaline sized	Alkaline sized
Speed	
Held constant, 500 m/min	300-500-600 m/min
Starch parameters	
Chemical modification	Chemical modification
Molecular weight	Molecular weight
Solution solids	
8% and 12%	Maximum runnable

II. Modifications and ranges

Starch type	*Molecular weight × 1000*	*Solution viscosity, mPa·s at 50°C*
Pearl	1000-1150	90-230
Cationic	1360-1575	30-120
Oxidized	130-845	20-30
Esterified (acetylated)	855-1000	30-70
Etherified (hydroxyethylated)	480-1800	35-200

of 60 cp (60 mPa·s) unless the temperature of the film can be maintained at or above the 140°F (60°C) level. A chemically substituted starch (e.g., hydroxyethylated, acetylated, cationic, or highly oxidized) eliminates or reduces retrogradation below the level at which it causes runnability problems.

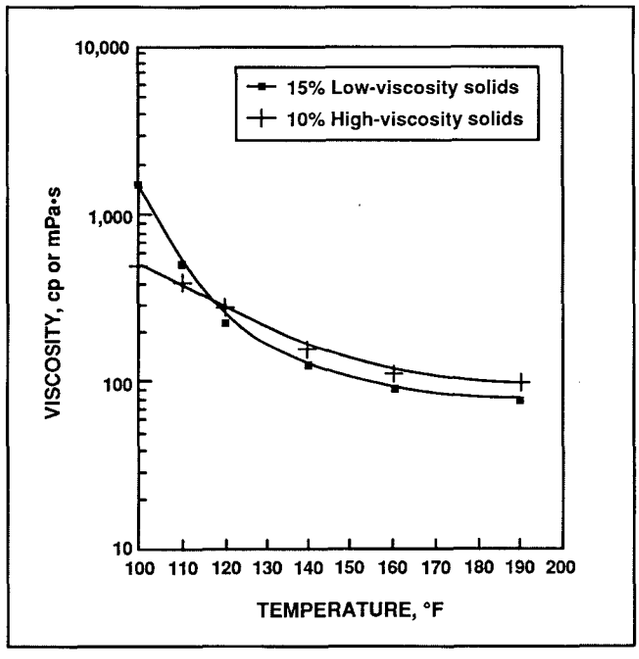
Limits on the operating conditions of a metered size press, just as in a flooded-nip size press, are imposed by solution viscosity and molecular weight, even when using modified starches. The operating range for the flooded-nip size press is, however, much narrower. Starch solution viscosity in a flooded nip is limited to a maximum of about 50 cp (50 mPa·s) by "splashing" of the pond. A metered size press eliminates the "splashing" by eliminating the pond.

In addition, with a conventional size press at a given size-press nip pressure, as the viscosity increases the starch pickup increases if other factors are held constant. A metered size press's design allows for controlling the coat weight independently of starch solution viscosity, machine speed, or starch solids (*3*) by means of pressure and angle on the metering blade or size of the wire on a rod.

Picking of fibers from the web becomes the limiting factor to the starch solution viscosity. Therefore, surface strength of the base sheet will play a role in determining the upper viscosity limit of the solution. Viscosity, and indirectly size-press roll tack, of a starch solution is controlled by the molecular weight of the starch and the solids level of the solution. For the two base sheets run during this trial, surface picking began to occur over a range of 100 cp to 150 cp (100-150 mPa·s).

Also, the technique used to develop viscosity played a role in determining the viscosity at which picking occurred. When viscosities were developed using a high-molecular-weight starch at low solids, there was less surface picking than when the same viscosity was developed using a low-molecular-weight starch at high solids. This is explained by comparing the temperature-viscosity response curves, as demonstrated in **Fig. 1**, with two molecular-weight versions of a cationically substituted starch.

1. Temperature-viscosity relationship in cationic starch

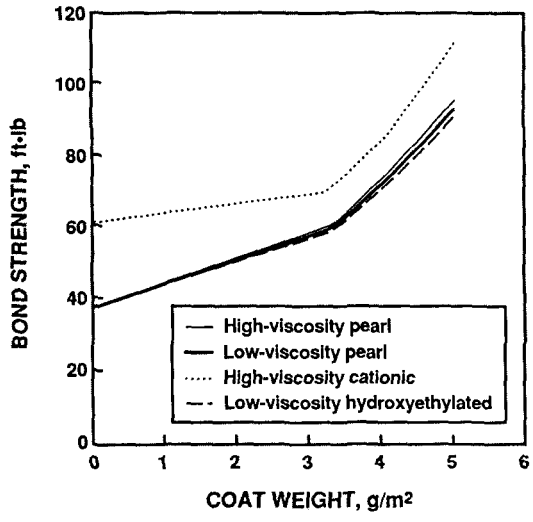


Paper properties

Five starches varying in chemical composition were compared in these trials. These were cationic, hydroxyethylated, acetylated, oxidized, and acid-thinned pearl (to simulate ammonium persulfate or thermal- or enzyme-thinned pearl starch). These substituted starches were further modified to reduce the molecular weights to different levels.

Two base sheets, one produced in France (75 g/m²) and one produced in the United States (82 g/m²), were surface sized. These sheets were then evaluated for mechanical properties, optical properties, and printability. Because the same trends were seen with both base sheets, the

2. Scott bond on French base sheet



III. Scott bond data

	Coat weight, g/m²	Scott bond, ft·lb	Wax pick
Pearl starch			
Low viscosity	3.50	57	12
	4.45	77	14
	5.54	140	16
High viscosity	3.16	52	13
	3.56	62	14
	4.85	125	16
Cationic			
High viscosity	2.87	46	12
	3.73	77	14
	4.62	125	16
Hydroxyethylated			
Low viscosity	2.98	40	10
	3.63	49	14
	4.16	64	14

figures use only the data from the French sheet to improve clarity.

Starch applied on a blade-metered size press tends to remain primarily on the surface of the paper because of the reduced water levels at the time the film is transferred to the paper web. This is apparent in tests that measure the internal strength of the paper (**Fig. 2 and Table III**). There was little difference in bond strength between the starches used and only small increases in internal bond with increasing starch pickup. The surprising result is that mechanical properties dependent upon bulk (e.g., tensile, mullen, and tear) fall roughly along a common line when plotted against starch pickup.

Depositing the film on the paper surface also had an effect on the optical properties. Traditionally, starch deposited by a flooded-nip size press reduces GE brightness by as much as 2-3%. With the blade-metered size press there was a slight tendency toward lower GE brightnesses and opacities, but the loss was only 0.5% over a pickup range of 2.5 g/m² to 5.5 g/m² (80-150 lb/ton). Deposition of the film on the paper's surface affected only the air-fiber interfaces on the surface; the majority of them in the center of the web remained unaffected.

Printability

Printability was the one property that showed significant variations with chemical modifications.

Printing was evaluated on a four-color Heidelberg offset lithography press. A form developed for this project was composed of five-color photographs, including flesh tones, bright colors, and foods. Another photo was composed of black half-tones. Also, included were color bars, a color shade scale, and single-color screens.

As expected, a sheet without starch had severe picking. The oxidized starch performed well in the first unit, but, as the sheet contacted additional press units, picking became progressively poorer. It appeared that the carboxylic acid groups were more sensitive to the water-alcohol fountain solution than other modifications. Acid-thinned pearl starch did not pick; however, the color of this finished sheet was "washed out." The greater sensitivity of the pearl starch created difficulty maintaining the water-ink balance and allowed greater penetration of the ink into the sheet. The acetylated, cationic, and hydroxyethylated starches all had good printability.

Conclusions

Runnability of the metered size press was affected by both chemical modification and molecular weight of the starch. Thinned pearl starch has the potential to cause severe runnability problems. The technique for developing a given viscosity of the starch solution, by solids or by molecular weight, had a significant effect on the picking of the web and limited the maximum viscosity that could be run.

Because the starch film was deposited on the surface of the web, starches exhibited similar mechanical properties. Printability of the sheet, however, demonstrated differences based upon chemical modification. Hydroxyethylated, acetylated, and cationic-substituted starches had printability superior to oxidized and pearl starches.□

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