An Investigation of the Relative Water Holding Capabilities of Various Synthetic Adhesives

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AN INVESTIGATION OF THE RELATIVE WATER HOLDING CAPABILITIES OF VARIOUS SYNTHETIC ADHESIVES

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ABSTRACT

During the investigation of the water holding capacity of various latexes, the Hercules Size Tester, appeared to be the most consistent and convenient instrument for determining this characteristic. The latexes used in this investigation were those recommended by suppliers as excelling in this capacity.

It was hoped that a correlation could be found between water retention time and ease of obtaining gloss through super-calendering. However, no such correlation was found. In a routine control situation, through backlogging of data on.a unchanging coating system, a correlation would be more likely to appear.

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INTRODUCTION

Water retention, originally known as "coating holdup", was a relatively unconsidered and unexplored property of coatings until the late 1940's. Until that time, if the water retention of a coating color was even considered, it could not be measured with accuracy. As water retention became a more important topic of investigation, more effective means of measurement were sought and investigations were launched into the factors which effect water retention (8).

Numerous tests and equipment were devised to measure WRT (water retention time), but the most useful and accepted procedure to date was that developed by S.D. Warren Company. This procedure involved use of electrical conductance as its principal of operation and similar instruments using this same principle have been developed and up to the present time, used almost exclusively for measurement of WRT's. With new demands for more accurate and reliable methods, optical and sonic devises are gaining increased use. Most optical instruments measure the decrease in brightness or reflectance of the backside of a sheet which had been exposed to a dyed coating. The WRT is then determined as the time required to obtain a certain percentage of the original brightness.

Sonic instruments on the other hand, measure the change in velocity of sound as fibers swell from the water lost by the coating. Sound waves are passed through the sheet, and the WRT is measured as the amount of time required for the velocity to drop a predetermined amount (8).

LITERATURE SURVEY

Water retention is the capacity of a coating color to hold back its water and not to release it to the paper substrate. This is an important factor in papermaking because in order for the adhesive to give its best performance it must remain on the surface of the paper (9). The adhesive travels with the water and if the coating releases its water too easily, the binder and water will migrate into the sheet. This leaves the coating deficient in adhesive, causing dusting and other problems with the coated sheet. Water retention is also important because it directly affects the initial strike-in rate as well as drying rate and rheology.

Culp reported still another important factor affected by water retention; increase in solids occurs at the instant of application to the sheet. The increase is greatest at points closest to the surface of the web. With colors of initially high solid content, the increase of solids at the web surface causes increased resistance to flow. This in turn influences the splitting of the film as the web parts from the applicator roll. For example, if the coating color has a low water retention, the solids increase on the roll will cause a substantial increase in flow resistance of the coating. Therefore, the film will split close to the roll surface. The immediate effect is a much heavier film being carried away than is left on the roll resulting in an uneven coating applied to the sheets. In the case of extremely low water retention, a coating may even become unuseable due to drying on the roll. On the other hand, if the coating has a high water retention, the solids and flow resistance will remain constantly low, making it possible for better coater performance (9).

The effects of water retention on coating behavior is indeed important. The degree of water retention needed varies with specific performance required for the coating. In one application a color with low water retention may be allowable, perhaps even desirable, while in another case high water retention may be a necessity. Therefore, it seems less pertinent to discuss the importance of water retention and more pertinent to discuss these basic factors controlling water retention.

There are several factors which are important to the performance of a coating color in a water holding capacity. These are solids, temperature, type, and level of adhesive, and to a lesser degree, viscosity and pigment type. Also of great importance in the behavior of the coating is the type of base stock to which the coating is applied.

Increasing solids in the coating generally has the effect of increasing the WRT (water retention time) with the exception of coatings containing high levels of latex in the adhesive. In the case of high latex coatings the WRT actually decreases with increasing solids. This phenomenon is not completely understood, but is believed connected to the hydrophobic nature of latex adhesives (6,8). Taylor and Dill, also noted this reversal in starch and protein colors. As solids increased WRT's increased to a point, and after that point as solids increased WRT decreased. The explaination of this interesting phenomenon involves adsorption of starch or protein onto the pigment surface thus freeing water and lowering the water retention time (8).

Water retention is highly sensitive to temperature changes and decreases severely as the temperature raises between 50° and 90° degrees Farenheit. This is almost solely due to temperature and not to viscosity changes as might be expected, as viscosity has only a slight effect on water retention times (7,8).

Type and level of adhesive are probably the most predominent controlling factors in the water retention behavior of any individual coating. Generally, water retention increases with binder level, and increases more rapidly in a starch-latex or protein-latex system than in a pure starch or protein system. Taken individually, casein and protein have the best water holding performance. Starches have slightly lower to very much lower WRT values depending on the type of starch. Latex, due to its hydrophobic nature, shows very poor water holding properties. Increasing the ratio of latex while keeping the total binder level constant also decreases the WRT (6, 7, 8, 9).

As previously mentioned viscosity has little effect on the water holding behavior of coating colors. In separate experiments Taylor and Dill and Hagerman et al proved through the addition of synthetic thickeners, which themselves have no effect on WRT, that varying viscosity over a wide range had little to no effect on the WRT of the color. In this manner they were also able to prove that solids and viscosity have no relationship in there effect on water holding properties.

Pigment type and base stock effect WRT values, with the type of pigment being of only minor importance. Because the type of substrate was outside the realm of interest of this paper it will not be discussed except to mention its importance in the behavior of the coating. As for pigment type, clay gives the best WRT value and replacing clay with another pigment generally lowers the WRT. The effect of pigment type is of much greater importance at lower than 40% solids, and the replacement of clay by calcium carbonate causes a marked reduction in water retention in a binderless system. The pigment particle size and shape as well as its ability to attract and hold water are the important factors in pigment performance (7).

A knowledge of the mechanism of liquid migration is not of great importance in the control of water retention, however, it gives an insight into the reasons for a coatings behavior. The mechanism is essentially two stages. The first stage is a rapid penetration into "defect zones" or areas of low fiber content and pinholes, followed by a slower second stage of bulk migration into the total exposed area. Instrument measurement of water retention intergrates these two stages of penetration and the water retention time obtained is a result of the effects of both stages (1, 2, 3). In actual coater operation, the behavior of the coating can be solely dependent on the first stage or dependent on any combination of the two stages depending on the coater and base stock (1). The speed of the coater, the type of coating, and the type of base stock all weigh heavily on the coating performance. To take an example, assume a very high speed coater with a short distance between point of application of coating and removal of excess coating, and a base stock which is very open and unsized. In this case the coating behavior on machine would be much different than testing would indicate, coating behavior being almost totally controlled by first stage migration. On the other hand consider the situation of a slow, puddle type coater with a well formed sheet low in defect zones. In this case testing results would give a good indication of coating performance on machine with both stages taking part in the migration.

OBJECTIVE AND EXPERIMENTAL DESIGN

With the purpose in mind of carrying out a comparison of various latexes with claims for high water retention capabilities, an experimental procedure was arrived at which attempted to minimize systematic errors. In the actual testing for water retention, it was hoped that the Hercules Size Tester would prove to be a useful routine testing devise in this application, and to that end, all WRT's (water retention times) contained in this report were obtained with Hercules Size Tester. At the outset, it was also hoped that a correlation would be found between the WRT and ease of calendering for gloss.

Coatings were prepared at 50% solids using a high speed, high shear disperser. The pigment was dispersed first, with starch which had been cooked separately added after dispersion of the pigment was complete. The mixture was kept at low shear for sufficient time to insure complete blending. Finally the latex was added, and the color kept at low shear until complete blending was obtained.

In preparing coating samples for testing on the Hercules Tester aliquot portions of coating were taken and dye was added to obtain 1.25% dye by weight as recommended by Hercules for size test solutions. This ratio of dye also proved acceptable for WRT's. Cyanimide

Napthol Green dye was used as a ten percent solution. The base paper used in testing was S.D. Warren Standard paper specified in the industry for the WRT test.

The testing procedure for WRT consists of clamping standard paper in the rings supplied with the Hercules Tester and placing it in position on the testing instrument. The instrument was then set at 80% reflectance and calibrated. Finally, the dyed coating (approximately 10 cc) was poured quickly into the test ring while simultaneously starting the automatic timer on the instrument. The reading was recorded and sample discarded in preparation for another test.

Coated sampled for calendering and gloss measurement were made on a laboratory coater using a #14 rod with a machine speed of 22.5 fpm and coating formulations prepared as described earlier. All coating were reduced to the same viscosity for coating, consequently solids and coat weight varied for the different latexes used. Samples were calendered with four nips at 115°F and 40 pli. on a small laboratory calender. Gloss readings were taken at 75°.

PROCEDURE

Coating Formulations

50% Solids Coatings

Without Sodium Alginate:

1000g H_2O

854g No. 1 coating clay

86g Penford gum 280 (10% based on clay)

51.5g Latex (6% based on clay)

3.4g T SPP

With Sodium Alginate:

1000g H_2O

852g No. 1 coating clay

852g Penford gum 280

51.1g Latex

8.5g Sodium Alginate

3.4g TSPP

DATA

Analysis of S.D. Warren Standard Test Paper:

Caliper	.004 inches
Brightness	73.6
Opacity	94.7
Gurly Porosity	80.7 seconds
Hercules	unsized
Basis weight	$85 g/m^2$
Density	$.835 g/cm^3$
Ash	24.6%

TABLE I

Latex	Viscosity Brookfield Centipoise	Solids	WRT Average	WRT Range
Styrene Butadiene		60%	70.1	68.7 71.7
Styrene Butadiene	1500	50%	32.1	28.5 36.2
Acrylic Copolymer	1860	50% pH 9.3	94.7	90.5 101.8
Acrylic Copolymer	890	50% pH 6.1	26.0	23.6 28.6
Acrylic Copolymer	920	19% pH 9.5	81.6	78.5 96.6
S.B. & Sodium Alignate	7900	51%	100.2	89.2 109.2
S.B. & Sodium Alignate	3625	32.6%	66.7	62.3 69.3
S.B. & Sodium Alignate	1800	23%	47.6	45.3 51.3
S.B. & Sodium Alignate	1260	18.3%	41.6	37.2 46.0
PUA Copolymer	1480	50%	30.8	26.2 37.9

TABLE II

Latex	Solids	Viscosity Brookfield Centipoise	Weight	WRT	Gloss Average	Gloss Range
Styrene Butadiene	52%	2060	52#	Low	82.2	79.8 85.8
Acrylic Copolymer	47%	2000	50#	High	77.9	74.6 79.5
S.B. & Sodium Alignate	31%	2010	49#	Medium	73.5	70.5 75.0
Base Stock			40#			

DISCUSSION OF DATA

The water retention times obtained agreed well with previous work in the same solids range and using simular latexes (2). However, there was no correlation between water retention and ease of obtaining gloss through supercalendering.

The latex of lowest WRT gave the best gloss, while the same latex with 1% sodium alginate added and highest WRT gave the lowest gloss. The latex the highest WRT for latex alone produced intermediate gloss value. One might conclude from the data that gloss variations were caused by coat weight variations, however, this slight variation does not sum sufficient to explain the large difference in gloss values.

The latexes investigated were chosen because of manufacturer claims for high water retention. It is obvious however, not all of them gave high readings on the Hercules Size Tester. On the basis of equal solids and equal binder level the polyvinyl acetate copolyme gave the lowest water retention time. Styrene Butadiene gave a sightly higher value, while the acrylic copolymer gave a much higher WRT. Styrene Butadiene plus 1% sodium alginate gave the highest water retention, but this was only slightly higher than the acrylic copolymer.

CONCLUSIONS

There is no direct relationship between water retention times and gloss values, and it is apparent that there are other factors which affects gloss. One factor to consider is the latice structure of the dry coating and how it varies with the coatings.

Although no correlation was found between gloss and water retention, under routine productions conditions using one system, such a correlation might be found. Through backlogging of data on both gloss and water retention during good running conditions one would be able to determine if gloss problems were due to poor water retention when problems occur.

The Hercules Size Tester worked very well as a means for measuring water retention times, giving good comparison between undividual values, and being an uncumbersome and fast method for obtaining water retention times. It also gave values in excellent agreement with published values obtained by different devises on similar coating color systems. The Hercules Size Tester should prove to be a valuable and dependable testing instrument. Some problems were encountered, however, in testing coatings at above 50% solids. It was difficult to obtain rapid distribution of test coatings over the entire area of exposed paper at 60% solids.

While the alkali swellable acrylic copolymer and sodium alginate, modified styrene butadiene both gave high water retention times, both gave problems with handling at 50% solids due to their high viscosity at this solids level. The acrylic copolymer gave the added difficulty of pH sensitivity, and at low pH lost all its water retention capacity. The unmodified styrene butadiene and the polyvinyl acetate copolymer both gave very poor water retention times, however, both gave good flow and handling properties at 50% solids.

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