Paper Coating Mixture: Preparation, Application, and Study of Their Rheological Properties

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ABSTRACT: The finish obtainable on coated paper depends on the materials used as well as the way in which it is calendered. The rheological properties of the coated mixtures revealed the difference between them. When the apparent viscosity, η, was calculated and plotted against the shear rate, γ, on a log–log graph, an approximate linear relations were obtained. On the other hand, a plot is drawn between the shear rate and shear stress, in which a hysteresis loop is obtained connecting the up and down curves. It is clear from these plotting, that the rheological properties for the prepared coating mixtures show time-dependent behavior, because they are share rate dependence, and they can form sol–gel character. Moreover, the pigments used in the coating mixture were usually chosen because of their different impacts on coating color properties and also on the properties of the coating layer. Therefore, one can use the coating mixture to have higher optical properties and to improve the permeability of the sheets. © 2000 John Wiley & Sons, Inc. J Appl Polym Sci 77: 1666–1678, 2000

Key words: coated paper; coating mixture; rehological properties; shear rate; shear stress; time dependent; sol-gel character; pigments are permeability

INTRODUCTION

All papers subjected to coating were as uniform in formation and appearance as possible, taking into consideration the strength required in the coated paper and the nature of the fibers used.

The coating covers the individual fibers and fills any spaces between, so that when the paper is calendered it will have a smooth, even, and continuous surface, which takes the fine dots of a half-tone plate much more perfectly than the uncoated paper.[1] When we print on uncoated paper, we are attempting to lay a hydrophobic ink on a hydrophilic surface, because fibers are hydrophilic. The result is that we print in the interstices between the fibers, not on the fibers themselves.

The original pigment used for surface coating was clay, but modern practice has broadened the field to include many other pigments, such as blanc fixe satin white, precipitated chalk, lithopone, titanium dioxide, alumina, talc, etc., each of which has certain desirable characteristics.[2]

The adhesive in coated paper is chiefly casein, although starch and glue are sometimes used. Other adhesives that have been tried or proposed as casein substitutes include soya bean meal and the protein made from it, pectin, alginates, locust, bean gum, and synthetic resins of many kinds. Besides the two main ingredients in the coating mixture, other substances are often used in smaller amounts for special purposes such as increased flexibility.

The preparation of the coating mixtures has a considerable influence on the quality of the finished paper and on the economy of the process. The amount of water used in a coating mixture is usually governed by the necessity for making it spread without showing brush marks.[1] The finish obtainable on coated paper depends on the materials used as well as the way in which it is calendered.[3]

The rheological properties of the coated mixtures revealed the difference between them, and

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Journal of Applied Polymer Science, Vol. 77, 1666–1678 (2000)

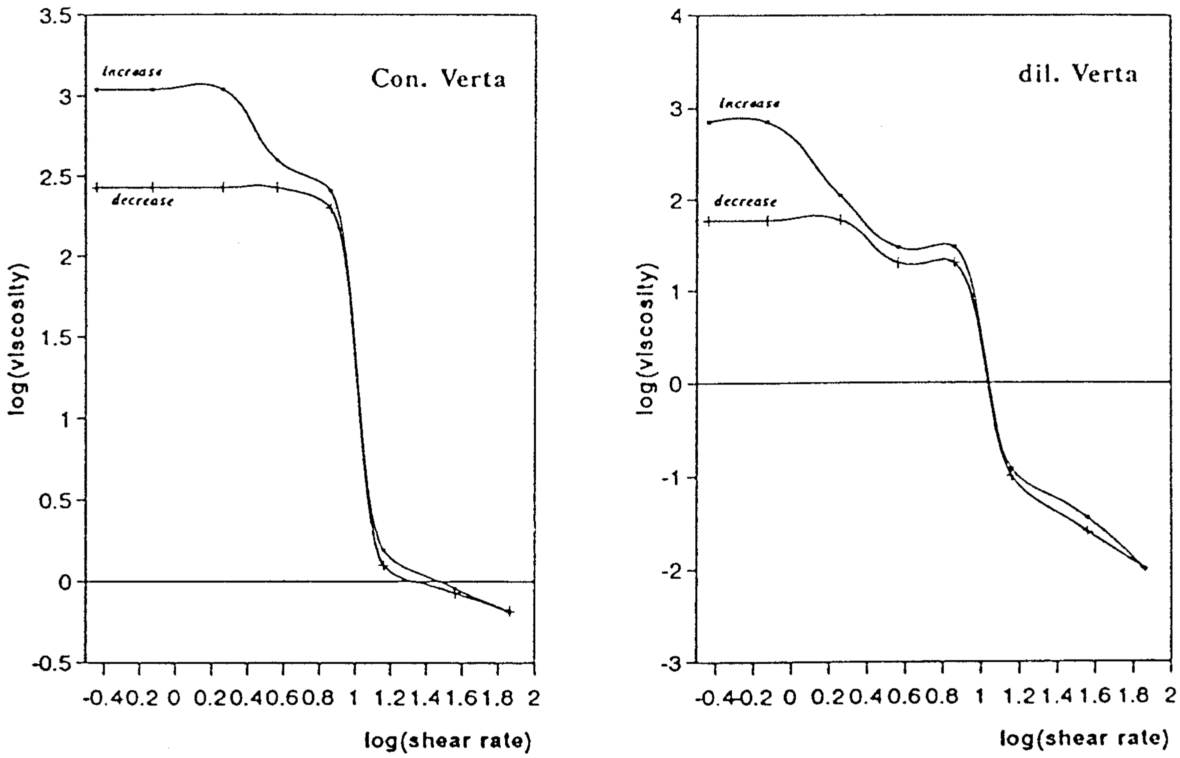

Figure 1 (a) Variation between the viscosity and the shear rate for concentrated and diluted Verta coating mixture at 25°C. (b) Variation between the viscosity and the shear rate for the laboratory prepared eight coating mixtures (1–8) at 25°C.

represent the measurement of the flow properties of the solutions to be applied on paper surface. An ideal or Newtonian liquid will exhibit a constant viscosity coefficient over a wide range of applied stress, and it will be independent of shearing duration or history. Suspensions, pastes, gels, and emulsions frequently behave in a manner intermediate between that of solid and a liquid. As an example, the extremely small stresses may show recoverable, time-independent deformation, followed by flow (plasticity). The flow may then increase proportionally with a further increase of the applied stress. In other cases, the pseudoliquid may show a viscosity that decreases with increasing the applied stress.[4] In the case of thixotropic fluids or solutions in which the structural viscosity is time dependent, a continuous decrease in viscosity occurs during filtration.

An idea of the importance of structural viscosity could be taken from the coating industry. In the coating operations, unless the coating mixture will have the proper flow properties, improper transfer of coatings will result and nonhomogeneous patterns will be produced. In brush coating of paper or fabrics, the best coating mixtures are those exhibiting Newtonian or slightly dilatant flow. For roll coating, higher yield point and greater plasticity are needed. A certain degree of thixotropy is desirable for high-speed roll coating. Thixotropy, which is also defined as sol–gel transformation, is characterized by the fact that at a constant shear stress, the viscosity does not remain constant, but decreases with time. If the shearing stress is stopped, the viscosity is raised again by time, and this could take from a few seconds to several days. From this, it is evident that thixotropy permits the coating mixture to flow out easily and produce a level surface. To construct the flow curve, the apparent viscosity of solutions were measured as a function of shear rate. Changes of shear rates were conducted once by increasing its magnitude to the maximum available value (up curve) and another by decreasing again to its original value (down curve).[5] Antithixotropy, on the other hand, is distinguished from thixotropy in that the rise in shear stress results in an increase in viscosity, and it is distinguished from structural viscosity in that recovery of the system is not instantaneous.[6]

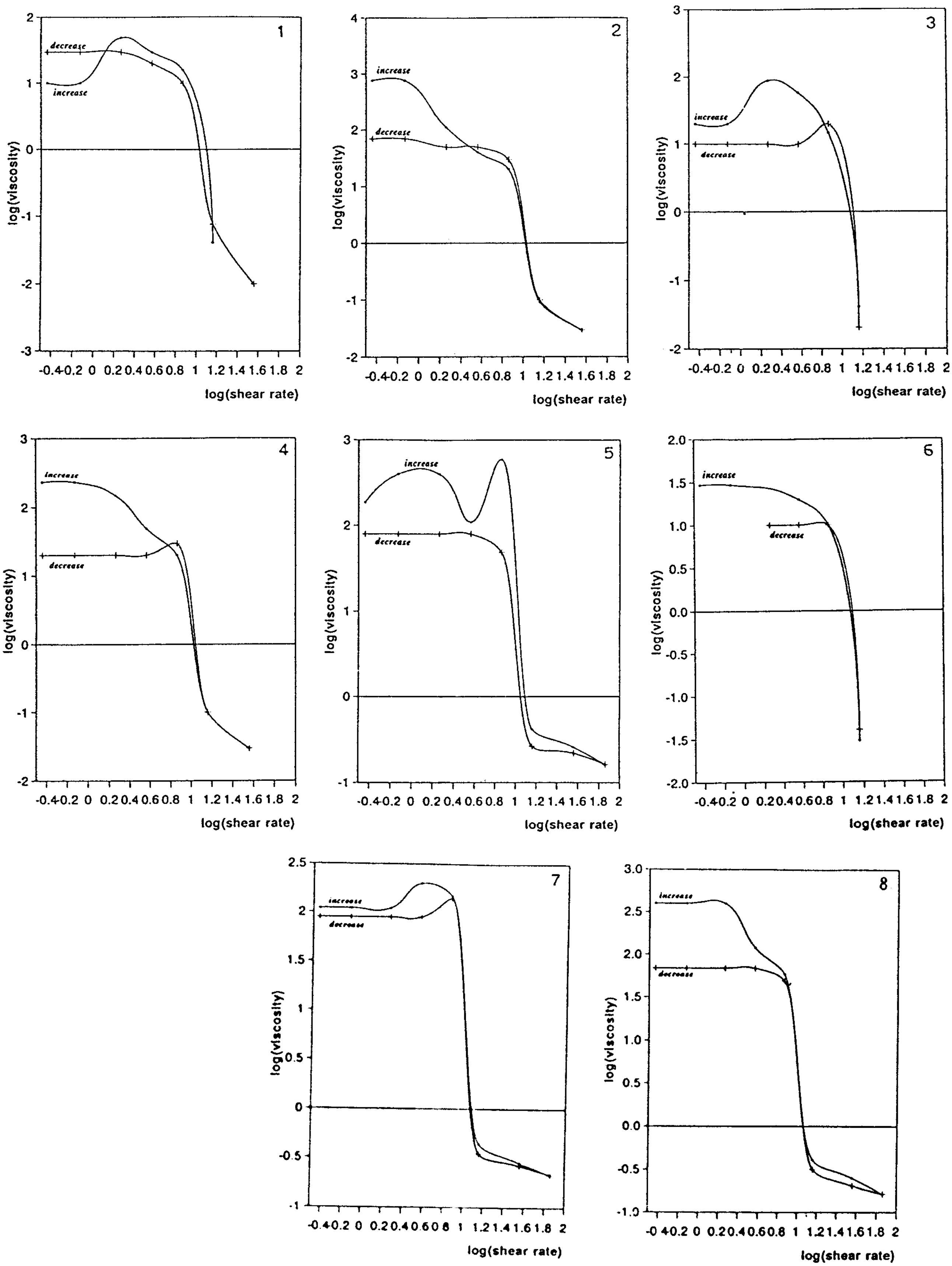

Figure 1 (*Continued from the previous page*)

Table I Rheological Characteristics of Coating Mixtures

Calculated Values	Conc. Verta		Dil. Verta		Mixture 1		Mixture 2		Mixture 3		Mixture 4		Mixture 5		Mixture 6		Mixture 7		Mixture 8	
	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.	Inc.	Dec.
Slope (s)	−0.45	−0.24	−0.9	−0.63	−0.5	−0.5	−1.0	−0.55	−0.76	−0.42	−1.0	−0.29	−0.71	−0.29	−0.63	−0.5	−0.33	−0.28	−0.63	−0.26
Area cm^2	2.67		8.92		3.28		2.27		1.867		3.27		2.35		3.33		1.88		2.27	

The present study aims to prepare paper coating mixtures from low-cost available raw materials, similar in their rheological and dispersion characters, to match and replace those imported and used industrially, and also to characterize the properties of papers coated with several mixtures made from these available low-cost materials.

EXPERIMENTAL

Industrial Coating Mixture

Industrial coating mixture was generously obtained from the Verta Company for Paper, Alexandria, Egypt, and composed of a dispersing agent, China Clay, and precipitated calcium carbonate as filler, styrene wax, optical brightener (Plankophor P), carboxymethyl cellulose, styrene butadiene copolymer, acrylic amionic as a binder, an insolubilizing agent, ammonia, polyvinyl alcohol (low viscosity), and water.

Preparation of a Laboratory Coating Mixture

In this study, eight coating mixtures were prepared in the laboratory using low-cost materials and compared with a Verta-coating mixture. Mineral particles intended for the coating of paper was surface treated with a copolymer based on vinyl alcohol. The mineral pigments used were clay and calcium carbonate. The mixture is consisted of clay 1.5 kg, calcium carbonate 0.5 kg, casein 0.18 kg, polyvinyl alcohol 0.05 kg, starch (oxidized starch) 0.04 kg, titanium dioxide (calcium sulfate) 0.02 kg, urea-formaldehyde 0.4 L (hexamine 0.18 kg and gelatin 0.18 kg), glycerin 0.4 L, optical brightener 0.04 kg, ammonia 0.32 kg, and water 1.6 L.

The chemical compositions of these eight coating mixtures can be classified as follows:

(1) Mixture number 1 contains: clay, calcium carbonate, casein, polyvinyl alcohol, ammonia, optical brightener, soluble starch, titanium dioxide, urea-formaldehyde, glycerin, and water (in a ratios mentioned above). (2) Mixture number 2: replacement of calcium sulfate (low-cost material) instead of titanium dioxide in mixture 1, produces mixture number 2. (3) Mixture number 3: This is as in coating mixture 1, but oxidized starch is used instead of the soluble starch. (4) Mixture number 4: This is as in coating mixture number 2, but oxidized starch is used instead of soluble starch. (5) Mixture number 5: As urea-formalde-

hyde is used as a water repellent, a decision was taken to replace it by a gelatin–hexamine mixture. The chemical composition is as mixture 1, but gelatin–hexamine is used instead of urea-formaldehyde. Mixture number 6: The chemical composition of the above coating mixture is the same as in coating mixture number 2, but gelatin and hexamine are used instead of urea-formaldehyde. (6) Mixture number 7: The same as in coating mixture number 3, but gelatin and hexamine are used instead of urea-formaldehyde. (7) Mixture number 8: The same as in coating mixture number 4, but gelatin and hexamine are used instead of urea-formaldehyde.

Rheological Properties

Rheological properties of the laboratory prepared coating mixtures, as well as the industrially used Verta-coating mixture, concentrated, and four times diluted with water, were studied using a Lab-Line Viscometer model 4537, in which a known volume of the sample was subjected at 25°C to different shear stresses. The viscosity, η, was calculated from the increased and decreased shear stress and the shear rate, using Spindle Setting 4, according to the following equation:

$$\text{Viscosity } (\eta)\ (\text{cP}) = (\text{Reading} \times \text{Factor}) - \text{correct for windage}$$

where, reading is the reading for the test material on the screen of the viscometer at specific shear rate; factor: it was supplied with the viscometer model, and it is 0.001 for speed-60, 30, and 12 rpm using spindle setting 4; correct for windage is 0.04 for the viscometer model 4537.

Paper Sheet Making

To make acceptable sheets for testing, six operations must be standardized: (1) preparing a uniform pulp suspension; (2) removing a representative sample of the paper size; (3) forming a uniform sheet; (4) couching; (5) pressing; and (6) drying.

The pulps used for paper making were bleached wood pulp, bleached rice straw pulp, and a bleached mixture of rice straw–bagasse pulp. The paper sheets were prepared according to the SCAN-C 26 : 27, SCAN-C 5 : 76 standard test method, then coated with the prepared coating mixtures and subjected to physical and mechanical testing.

Physical Tests of Hand-Made Sheets

After conditioning, the hand-made sheets were weighed and divided into suitable pieces for the physical tests. In accordance with standard method (1), the bursting factor, tensile strength, tearing resistance, brightness, opacity, and permeability of the sheets were measured. For each test, at least five experiments were carried out, and the arithmetic mean of the obtained results was calculated.

RESULTS AND DISCUSSION

Preparation of Paper Coating Mixtures From Low-Cost Substances and Study of Their Rheological Properties

The rheological properties of the coating mixtures were undertaken using a Lab-Line Viscometer model 4537, in which a known volume of the sample was subjected at 25°C to different shear stresses. For the industrially used coating mixture, it was concentrated and four times diluted with water and studied rheologically. The apparent viscosity, η, was then calculated using the following equation applicable for the above mentioned viscometer model:

$$\text{Viscosity } (\eta)\ (\text{Pa} \cdot \text{s}) = (\text{Reading} \times \text{Factor}) - \text{correction for windage}$$

If the apparent viscosities, η, were plotted against the shear rate, γ, on a log–log graph, approximate linear relations were obtained. The slopes of the resulting straight lines, $-d \log \eta/\log \gamma$, were utilized as a measure for the strength of solution structure.[7] On the other hand, if the logarithm of the shear stresses, ι, were plotted against the logarithm of the shear rates, γ, a straight line was obtained, the slope of which gives the value of s in the equation:

$$\iota = b\gamma^{s}$$

where s is designated as the pseudoplasticity, and b is taken as an indication of the viscosity. For Newtonian flows s equals 1, while for pseudoplas-

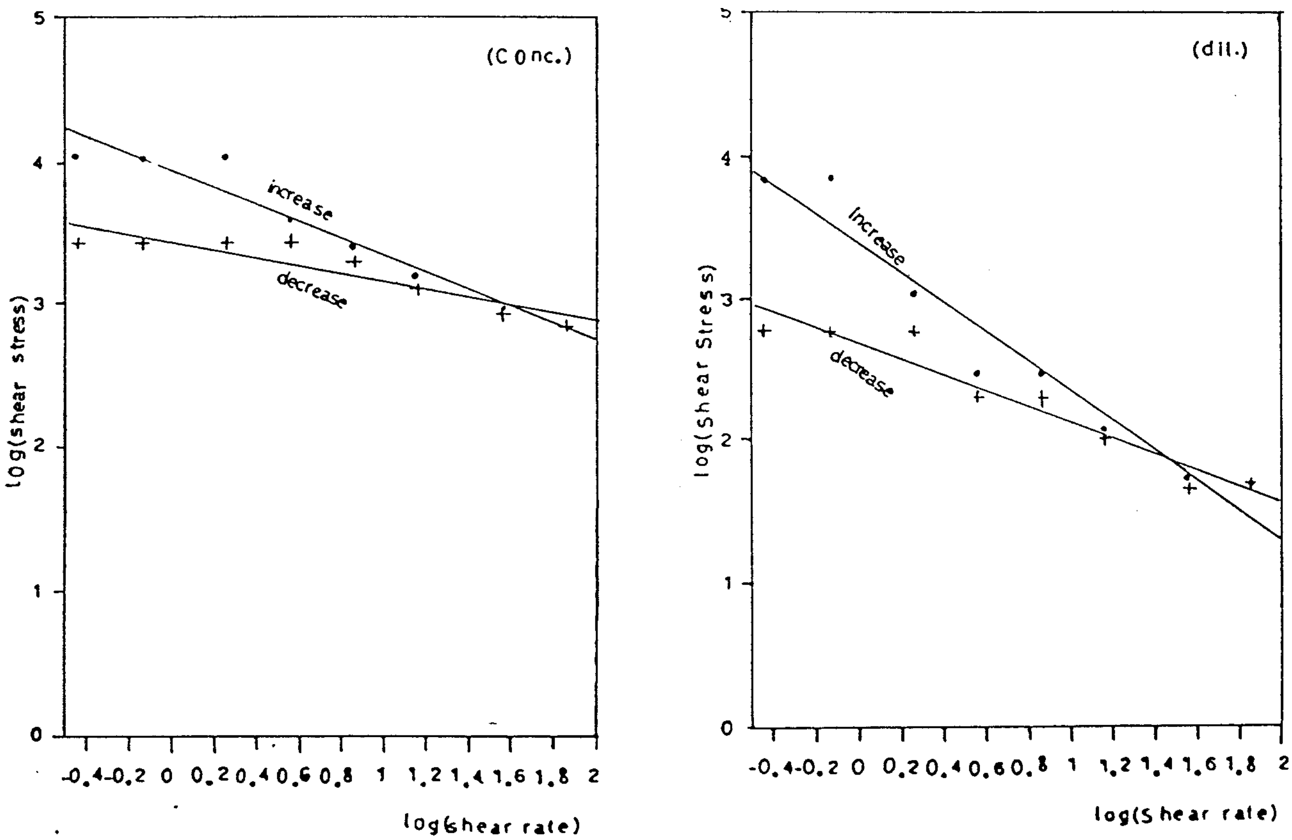

Figure 2 (a) Variation between the shear stress and the shear rate for concentrated and diluted Verta coating mixture at 25°C. (b) Variation between the shear stress and the shear rate for the laboratory-prepared eight coating mixtures (1–8) at 25°C.

tic flows, the value of s is less than 1, and for dilatant ones s exceeds 1.[6]

In this work, the rheological characteristics of the industrial mixtures (concentrated and diluted Verta-coating mixtures), as well as the laboratory-prepared eight coating mixtures were investigated and represented in Figures 1(a) and 1(b), in which log viscosity was plotted against log shear rate. It is clear that a sharp decrease in the viscosity values, of either industrial (concentrated and diluted) or laboratory-prepared mixtures, applying shear rates between 6.3 and 15.8 s^{-1}, in both cases increasing and decreasing.

The results, which are collected in Table I, showed that the slopes, s, of the straight lines of the log ι − log γ plots are less than unity for both industrial (concentrated and diluted Verta-coating mixture) and laboratory prepared coating mixtures [see Fig. 2(a) & 2(b)], which indicate that they behave as non-Newtonian solutions, especially as a pseudoplastic flow.

Generally, the rheological properties of the laboratory-prepared eight coating mixtures appear to possess a similar behavior as the industrial ones, which indicate that they are more or less similar to the industrial mixtures, and the most suitable contents of the prepared mixture composed from the following:

clay, calcium carbonate, casein, polyvinyl alcohol, ammonia, optical brightener, oxidized starch, calcium sulfate, gelatin and hexamine, glycerin, and water.

However, the difference observed in the rheological properties of the coating mixtures is attributed to the difference in the composition of the mixtures. The hysteresis loop produced by nonlinear up and down curves on plotting shear stress against shear rate [Fig. 3(a) and 3(b)], has been taken as a measurement of the thixotropy and antithixotropy indices, which were measured by determining the areas between the up and down curves (Table I). From these figures, time-dependent flow curves were illustrated, in which at a given shear rate the ascending and descending curves show different values for the shear stress because of the con-

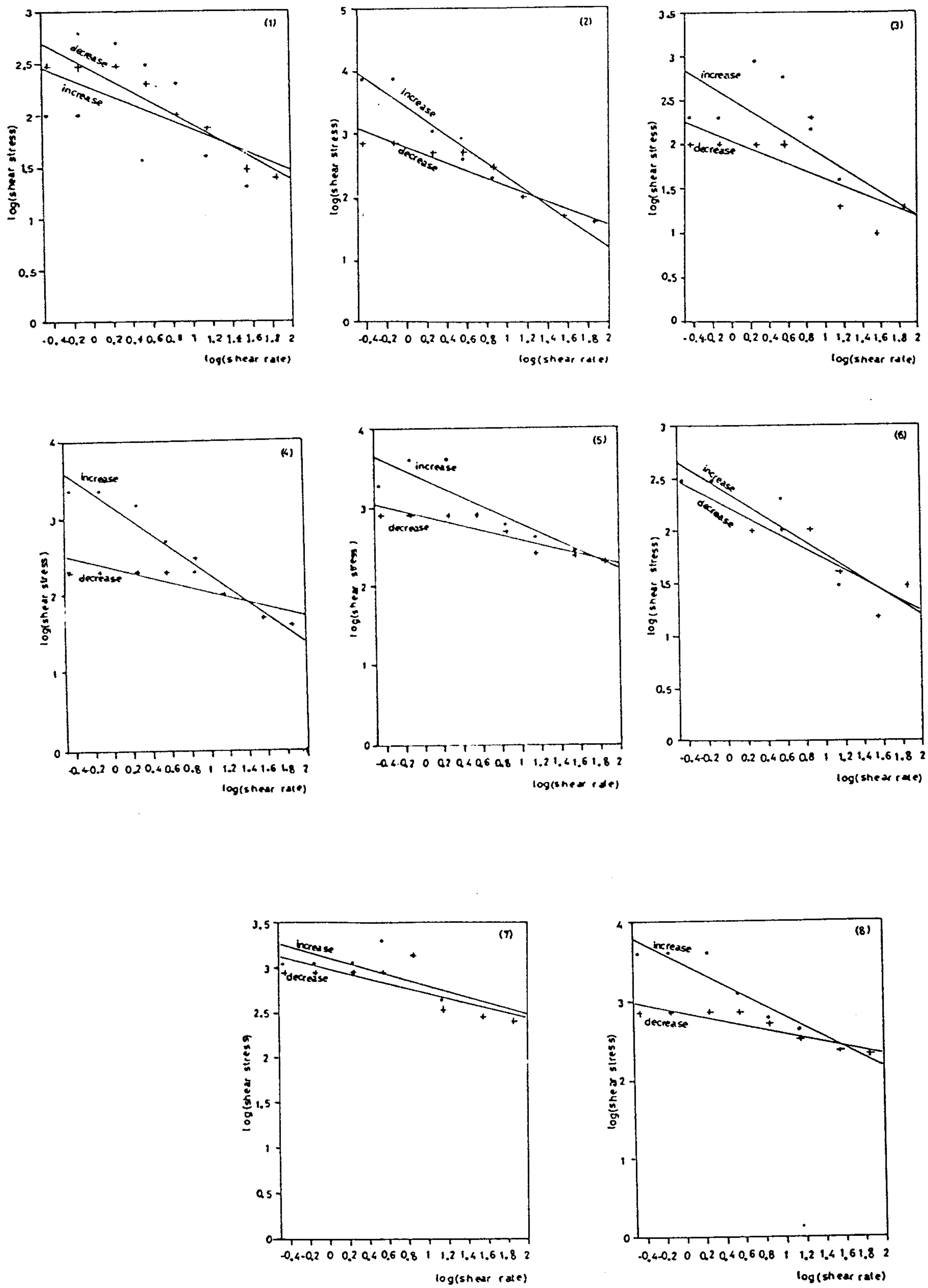

Figure 2 (*Continued from the previous page*)

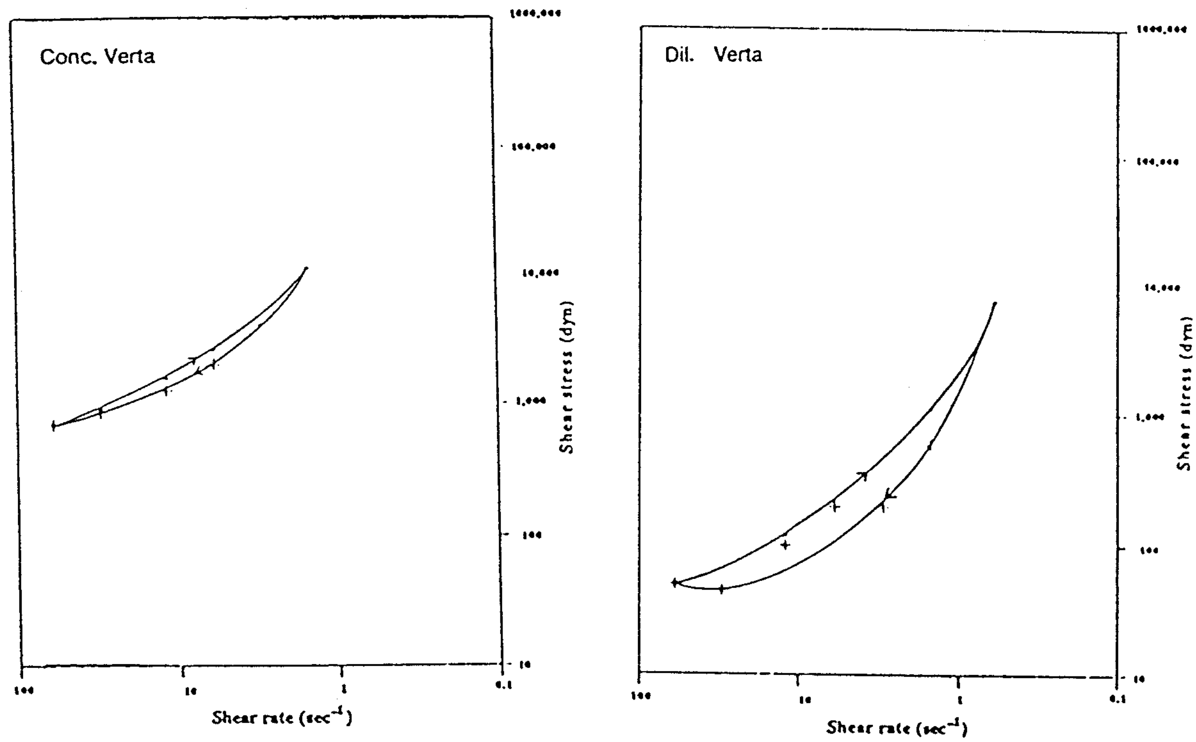

Figure 3 (a) Hysteresis loop curve for concentrated and diluted Verta coating mixture at 25°C. (b) Hysteresis loop curves for the laboratory-prepared eight coating mixtures (1–8) at 25°C.

tinued shearing. According to Ree and Eyring,[8] two kinds of molecules—extended entangled and coiled disentangled—exist in a flow system of thixotropic substances; the former are non-Newtonian in their flow, and the latter are Newtonian. The relative amounts of the two kinds of molecules are determined by the equilibrium constant for entangled molecule–disentangled molecule. The equilibrium is shifted at high stresses to the right and the entangled molecules are stretched, disentanglement is promoted, and the network structure is thus destroyed. Also, thixotropy and antithixotropy are related to differences in the rates of bond breaking and reformation, where, in the former case, the rate of reformation is slower than that of breaking, while the reverse takes place in the latter case, i.e., rate of reformation is higher than that of breaking.[9]

In this connection, it has been found that pigment type and different substituents affect the bonding systems in the mixtures and, consequently, the rheological properties. The presence of kaolin in the suspensions behaved like non-Newtonian fluids exhibiting either shear-thinning or shear-thickening effects,[10] so the rheological behavior of binder-containing kaolin coatings significantly depend on their composition. Mixtures containing casein were thixotropic, and their viscosity increased with the casein content. Mixtures containing starch or oxidized starch had lower viscosity than those containing casein, and in this case, it exhibited antithixotropic behavior at short shear times.[10]

Such differences in the thixotropic behavior may be ascribed to some specific conformation interactions between the pigments and the other ingredients, which lead to a pH-insensitive gel structure of the coating mixture. It is worthy mentioning that by the incorporation of some polymers into an aqueous ink solutions, the formed weak gel structures were insensitive to both the pH and to the presence of surface active agents.[11]

Coating of Paper with The Prepared Mixtures and Study of Their Properties

The rheological properties of the coating mixture have their effects on the coating process. These

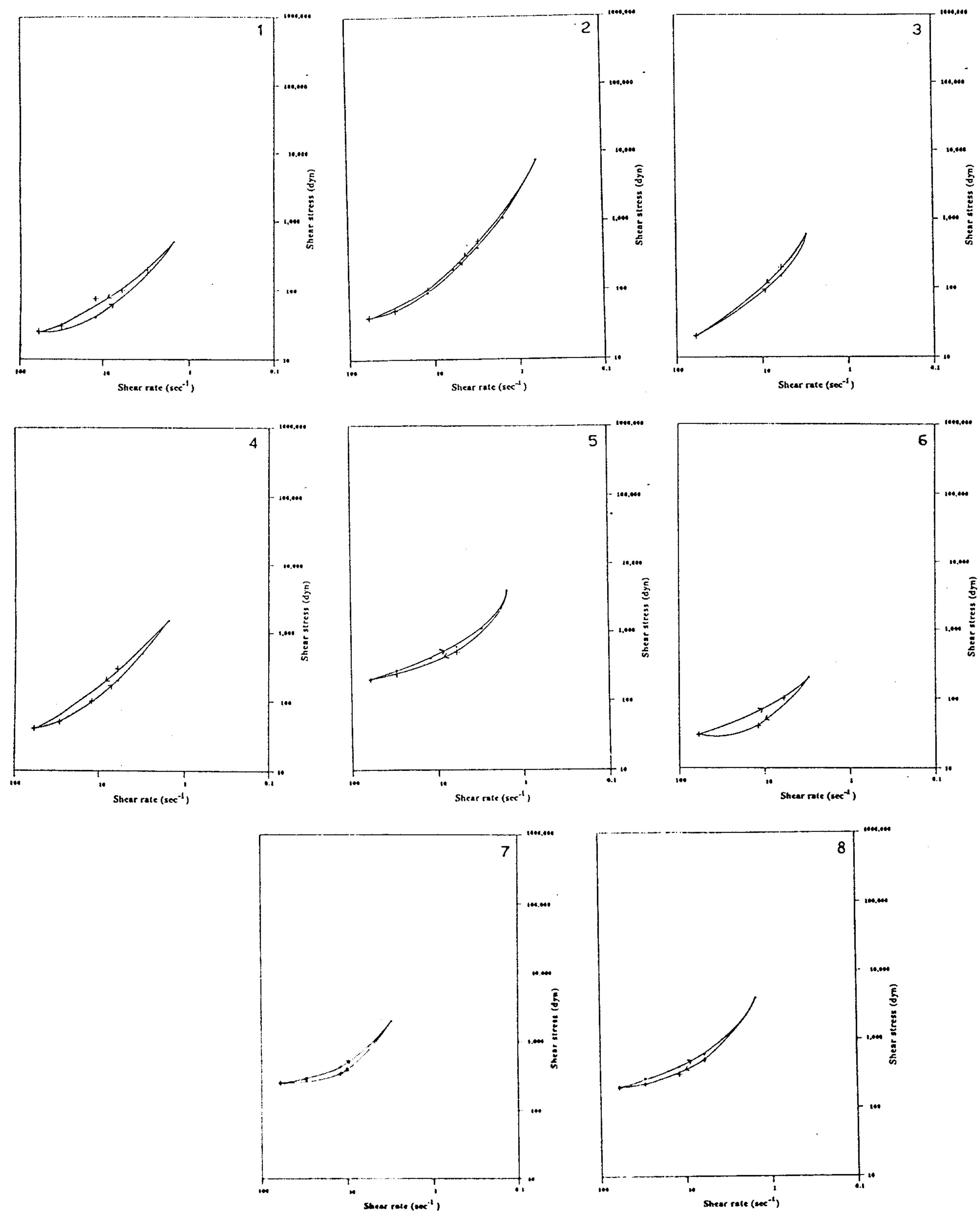

Figure 3 (*Continued from the previous page*)

Table II Optical and Mechanical Properties of Coated and Uncoated Paper Sheets Made from Wood Pulp

Sample	Tear Factor (100 g power m^2/g)	Breaking Length (m)	Burst Factor ($g/cm^2 \cdot m^2/g$)	Permeability (cm^3/min)	Brightness %	Opacity %
Uncoated paper	141 ± 6	5777 ± 208	2.48 ± 0.29	2200 ± 100	71.1 ± 0.1	82.2 ± 0.2
Coated with conc. Verta	96 ± 5	3434 ± 104	1.95 ± 0.19	80 ± 10	87.5 ± 0.2	99.5 ± 0.2
Coated with dil. Verta	82 ± 4	3316 ± 102	1.44 ± 0.14	85 ± 13	88.5 ± 0.2	93.3 ± 0.1
Coated with lab. No. 1	172 ± 6	2480 ± 106	1.36 ± 0.15	111 ± 28	86.0 ± 0.1	100
Coated with lab. No. 2	53 ± 7	2771 ± 99	2.49 ± 0.25	18 ± 3	86.0 ± 0.1	100
Coated with lab. No. 3	90 ± 7	1694 ± 95	1.14 ± 0.11	250 ± 50	86.0 ± 0.1	100
Coated with lab. No. 4	117 ± 4	2932 ± 196	1.81 ± 0.18	37 ± 4	85.0 ± 0.2	100
Coated with lab. No. 5	120 ± 6	2450 ± 87	1.43 ± 0.14	110 ± 15	86.0 ± 0.1	100
Coated with lab. No. 6	70 ± 7	2510 ± 84	1.45 ± 0.15	295 ± 21	85.0 ± 0.1	100
Coated with lab. No. 7	90 ± 7	1690 ± 90	1.14 ± 0.10	250 ± 50	86.0 ± 0.2	100
Coated with lab. No. 8	86 ± 3	2089 ± 106	1.42 ± 0.20	104 ± 34	85.0 ± 0.3	100

effects may be contributed to the fact that the coating process, namely the roll method, is time dependent. This means that the coating mixture must be spread homogeneously on the surface of the paper, i.e., the solution must be in a sol form. Thereafter, the sol must be transferred in a gel form. Therefore, the coating process is a sol–gel. The time of the sol–gel transformation is very important to define the success of the coating process. One of the objectives of coating is to form a continuous layer of coating over the surface of the body stock. Obviously, to do so the coating must be retained and dried on the surface of the body stock.

The simplest type of coating that might be used is one composed of a finely divided mineral pigment such as clay, and an adhesive such as casein or starch. The insoluble pigment, clay, will be in colloidal suspension, whereas the casein or starch will be in a true or colloidal solution. The percentage of solids will range from 35 to possibly 65%.

Hand-made sheets made from bleached wood, rice straw, and mixture of rice straw and bagasse pulps were coated with concentrated and diluted industrial coating mixture (Verta mixture), as well as with the laboratory prepared coating mixtures, applying the Roll method. The optical and mechanical properties were studied, and the results of investigation are given in Tables II–IV.

Comparing the properties of coated papers with those of uncoated papers made from the three different pulps (see Tables II–IV), shows that all optical properties increased upon coating, while the mechanical properties decreased, except the tear factor for the coated papers made from bleached wood pulp when using the laboratory-prepared coating mixture number 1, and the burst factor for the same coated papers but upon coating with the laboratory-prepared coating mixture number 2. On the other hand, the permeability decreased on coating, i.e., the coated sheets prove to have better water-repellent character.

Comparison between the properties of the three coated papers made from bleached wood, rice straw, and mixture of rice straw and bagasse pulps, coated with the laboratory-prepared coating mixtures and those coated with industrially used coating mixture (Verta mixture) (Tables II–IV), indicates that the tear factor is improved for the coated papers made from both bleached wood pulp and bleached mixture of rice straw-bagasse pulp when using the labora-

Table III Optical and Mechanical Properties of Coated and Uncoated Paper Sheets Made from Mixture of Rice Straw and Bagasse Pulp

Sample	Tear Factor (100 g power m^2/g)	Breaking Length (m)	Burst Factor ($g/cm^2 \cdot m^2/g$)	Permeability (cm^3/min)	Brightness %	Opacity %
Uncoated paper	29 ± 2	1248 ± 88	0.24 ± 0.06	1233 ± 60	71.0 ± 0.2	93.2 ± 0.7
Coated with conc. Verta	27 ± 2	1051 ± 50	0.23 ± 0.03	95 ± 5	81.0 ± 0.4	96.4 ± 0.2
Coated with dil. Verta	20 ± 2	760 ± 38	0.17 ± 0.01	145 ± 23	79.0 ± 0.3	93.7 ± 0.3
Coated with lab. No. 1	18 ± 1	873 ± 51	0.22 ± 0.01	138 ± 56	80.5 ± 0.2	100
Coated with lab. No. 2	24 ± 3	682 ± 40	0.17 ± 0.02	166 ± 70	84.0 ± 0.2	100
Coated with lab. No. 3	22 ± 1	941 ± 37	0.24 ± 0.04	160 ± 53	84.0 ± 0.2	100
Coated with lab. No. 4	24 ± 3	772 ± 41	0.18 ± 0.02	240 ± 98	82.0 ± 0.1	100
Coated with lab. No. 5	19 ± 1	870 ± 27	0.21 ± 0.03	137 ± 15	80.0 ± 0.1	100
Coated with lab. No. 6	17 ± 1	984 ± 36	0.23 ± 0.02	88 ± 5	79.0 ± 0.2	100
Coated with lab. No. 7	21 ± 2	940 ± 32	0.24 ± 0.04	158 ± 20	84.0 ± 0.1	100
Coated with lab. No. 8	16 ± 1	447 ± 31	0.24 ± 0.03	210 ± 90	82.0 ± 0.1	100

tory prepared coating mixtures numbers 1, 4, and 5, while the breaking length for coated papers made from bleached rice straw pulp using laboratory coating mixtures numbers 1, 3, 4, 5, 7, and 8 is improved, and the burst factor is improved for coated papers made from both bleached wood pulp, and bleached rice straw pulp on using the laboratory prepared coating mixtures numbers 2 and 4, and 1, 4, 5, and 8, respectively. On the other hand, the permeability improved for coated papers made from bleached wood pulp, bleached mixture pulp, and bleached rice straw pulp upon using the laboratory-prepared coating mixtures numbers 2 and 4, 6, and 1 and 5, respectively. Furthermore, the optical properties are improved for all coated papers using the different laboratory prepared coating mixtures.

Generally, it is known that contact between base paper and water occurs during all stages of paper treatment, such as sizing, coating, and printing. Also, it is well known that the roughening of a paper surface will occur during such water contacts as a result of distortion of the fiber network in the paper followed by a reduction in gloss value.[12]

The pigments used in the coating mixture were usually chosen because of their different impacts on coating color properties and also on the properties of the coating layer. Clay pigments are known to cause adsorption of carboxymethyl cellulose, possibly due to hydrogen bonding.[13] It has also been suggested that ground calcium carbonate pigments cause a lack of adsorption due to the hydrophobic nature of the particle.[14]

The pigment, however, creates a surface that is sensitive to expansion of the fiber network. The shape of the pigment particles also has to be taken into consideration when discussing differences between two coated surfaces containing different pigments. The shape of the pigment particle generally determines the contact area between two particles, roughly spherical particles having less contact with each other. Coating colors based on ground calcium carbonate (ground $CaCO_3$) may be more sensitive to expansion of fiber networks followed by fiber rise due to the spherical shape of $CaCO_3$ particles. Spherical calcium carbonate (SCC) pigment has been developed for use in coated papers of low gloss. The SCC produced coated sheets with the best overall balance of

Table IV Optical and Mechanical Properties of Coated and Uncoated Paper Sheets Made from Rice Straw Pulp

Sample	Tear Factor (100 g power m^2/g)	Breaking Length (m)	Burst Factor ($g/cm^2 \cdot m^2/g$)	Permeability (cm^3/min)	Brightness %	Opacity %
Uncoated paper	43 ± 5	4837 ± 202	2.12 ± 0.25	80 ± 10	71.0 ± 0.2	98.7 ± 1.2
Coated with conc. Verta	43 ± 5	3151 ± 45	1.40 ± 0.05	20 ± 1	85.0 ± 0.3	98.8 ± 0.3
Coated with dil. Verta	30 ± 3	1846 ± 30	1.35 ± 0.05	32 ± 4	83.3 ± 0.2	98.8 ± 0.3
Coated with lab. No. 1	32 ± 3	3886 ± 55	2.06 ± 0.06	15 ± 2	81.0 ± 0.1	100
Coated with lab. No. 2	21 ± 1	2654 ± 46	1.62 ± 0.08	21 ± 3	83.0 ± 0.1	100
Coated with lab. No. 3	29 ± 2	3484 ± 50	1.58 ± 0.07	28 ± 3	81.0 ± 0.1	100
Coated with lab. No. 4	27 ± 2	3242 ± 46	1.86 ± 0.11	21 ± 3	82.0 ± 0.2	100
Coated with lab. No. 5	32 ± 4	3768 ± 60	2.04 ± 0.21	15 ± 1	81.0 ± 0.1	100
Coated with lab. No. 6	32 ± 4	2468 ± 55	1.34 ± 0.07	61 ± 6	78.0 ± 0.1	100
Coated with lab. No. 7	28 ± 2	3470 ± 50	1.44 ± 0.07	28 ± 3	81.0 ± 0.1	100
Coated with lab. No. 8	23 ± 1	3197 ± 48	1.83 ± 0.10	30 ± 2	81.0 ± 0.1	100

optical, physical, and print properties.[15] With plate-like clay particles, on the other hand, there is a much greater potential contact area between-particles, although this depends on their orientation.

Grön et al.[12] stated that the coating colors, based on $CaCO_3$ pigments, cause a higher degree of both surface roughening and cracking than coating colors in which clay was used as the pigment. The distortion of the surface is due to contact with water during the wetting procedure and due to rising of the long fiber fraction. The shape of the pigment particle determines the contact area between particles in a dried coating layer. The recovery of the cracks is also related to the quantity and molecular mass of the water-soluble thickener for ground $CaCO_3$ coating colors. Clay-based coating colors are generally more resistant towards surface roughening caused by fiber expansion or fiber rising, and no significant cracking occurs in the surface.[12]

CONCLUSIONS

1. The rheological properties for the prepared coating mixtures show time-dependent behavior, because they are share rate dependent, and they can form sol–gel character, so they can be easily used on coating of the hand-made paper sheets.
2. Despite the decreased viscosity of the prepared coating mixtures, their efficiencies and their rheological properties are similar to that delivered from industry.
3. Hand-made sheets paper coated with laboratory-prepared coating mixtures prove to have higher optical properties compared to that coated with an industrial coating mixture (Verta mixture). Generally, one can use the coating mixture to have higher optical properties and to improve the permeability.

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