

Latex binder modification to reduce coating pick on six-color offset presses

Ron L. Van Gilder and Roger D. Purfeerst

ABSTRACT: *The fast-setting inks used on multicolor offset presses can cause coating pick, especially on coatings containing a linear carboxylated styrene-butadiene polymer, which is added to improve blister resistance. If ink tack builds too quickly, coating pick can occur at downstream color stations. The rate of build is affected by the interaction between the latex polymer and the solvents in the ink. Polymer solubility is known to be dependent on the polymer's physical state (linear vs. crosslinked) and its chemical structure (surface energy/polarity). Modifying the latex polymers to a higher level of surface energy/polarity reduced the interaction between ink and polymer, thus slowing the rate of ink-tack build. The surface-energy/polarity modification of linear polymers resulted in excellent blister-resistant coatings that ran on a commercial six-color press without showing coating pick.*

KEYWORDS: *Coatings, color printing, ink, latex, offset presses, picking, polymers, printing machines, runnability, solubility, tack.*

The runnability of coated papers on commercial offset presses with six, seven, or eight color stations can be influenced significantly by the rate of ink-tack build in the layer of printed ink. Ink tack increases upon the loss of vehicle from the ink when it is printed on the coated paper.

Background

Previous work has indicated that an ink layer printed at an early color station and not overprinted until it reaches the blankets of later stations can undergo an unacceptable increase in tack (1, 2). Some of this ink can transfer from the coated paper

to the blanket. If the level of ink tack exceeds the strength of the coating during the ink-splitting action, then an undesirable transfer of coating to the blanket will occur. This phenomenon is commonly referred to as "carryover piling" and is more concentrated at the trailing edge of the printed image. Such a problem results in press shutdown for blanket cleanup, with a loss of productivity.

A fast rate of ink-tack build and subsequent coating pick on the press have caused problems with a variety of coatings. The problems have been particularly troublesome for coatings containing linear polymers, which are added to improve the coating's blister resistance during web-offset printing.

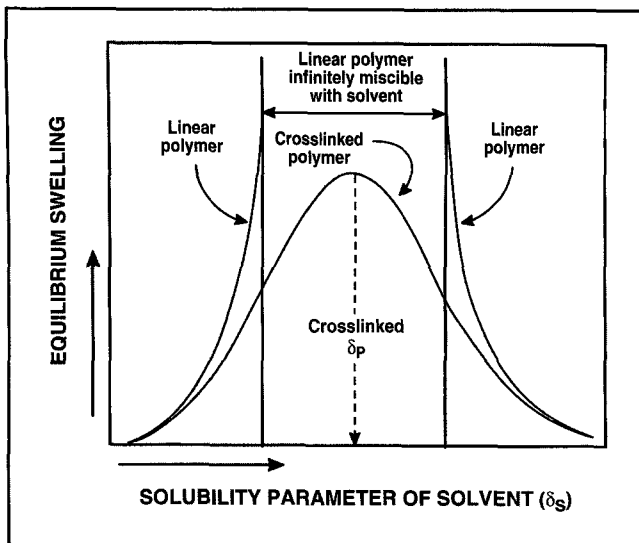
The effective tack of the ink and the tack-building process are functions of the coating's absorptive capacity, the ink formulation, and the contact time in the press (3). The press blankets also have different ink-setting rates and thus affect the tack of the ink (4). The latex binder in the coating can also influence the ink-tack-building process.

Ink components

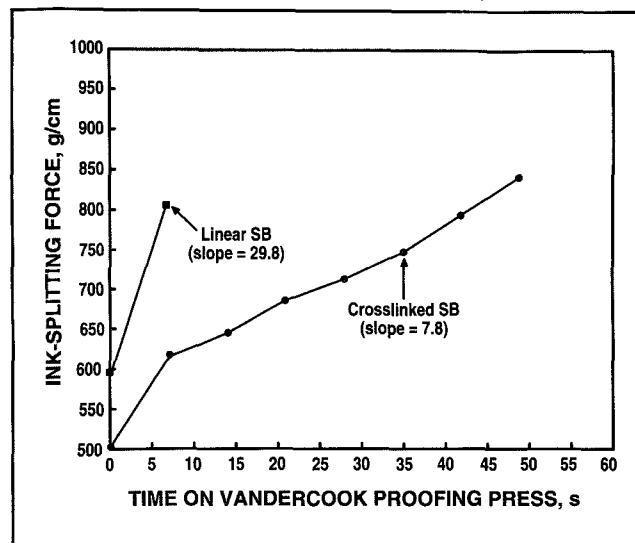
A typical lithographic ink formulation consists of three parts: the ink vehicle, the pigment, and additives. The ink vehicle consists of resins, plasticizers, gelling agents, and solvents. While each component contributes to the vehicle performance, the resin is the backbone of any ink

Van Gilder, associate scientist, and Purfeerst, industry specialist, are affiliated with Dow North America, Midland, MI 48675.

1. Equilibrium swelling of polymer in solvent as a function of δ_s for linear and crosslinked polystyrene [adapted from Van Krevelen (7)]



2. Ink-splitting force as a function of time on the Vandercook proofing press for coatings containing Class I polymers



I. Solvents used in laboratory experiments

Solvent	Solubility parameter (δ_s), (cal/cm ³) ^{1/2}
n-Pentane	7.0
n-Heptane	7.4
Offset-ink solvents	7.4–7.8
Methyl cyclohexane	7.8
Cyclohexane	8.2
Toluene	8.9
Dichloromethane (methylene chloride)	9.7
Acetonitrile	11.8

vehicle. Among the important resin properties—pigment wetting, gelability, softening point, viscosity, etc.—its solubility plays a key role in resin performance (5). Petroleum-distillate ink oils with different boiling points are commonly used as solvents for the different resins. Earlier work showed that these solvents affected the latex polymer in the coating during printing and influenced the ink-setting time.

Latex binders

Earlier work showed that the proper selection of latex binder in the paper coating can alleviate the problems of carryover-ink piling and coating pick

by prolonging the time required for the ink to set (6). These results were related to the absorption of ink solvent that occurs when the high-boiling-point aliphatic hydrocarbon solvent penetrates the pigmented latex coating. The amount of solvent absorbed and the linear increase or swelling of the latex film in the ink solvent were shown to be (a) dependent on the type of latex polymer and (b) correlated to the ink-setting behavior of the coating. For example, a latex that provided a long ink-setting time showed a lower linear increase of the film in the ink solvent, indicating good solvent resistance. A different latex absorbed a high amount of solvent, indicating poor solvent resistance, and resulted in a shorter ink-setting time.

The latex polymer with good solvent resistance prevented the ink solvent from migrating too quickly into the coating and, as a result, retarded the tack buildup in the ink layer. It was proposed that with good solvent resistance, the onset of critical tack could be delayed until after the last printing station, thereby minimizing the occurrence of carryover piling and coating pick (6). An ink-setoff problem, on the other hand, could be minimized by using a

latex binder with a poorer solvent resistance, allowing the coating to absorb ink vehicle at a higher rate. In this case, the ink setpoint would be reached in a shorter time.

This article builds on the earlier work of Kelly *et al.* (6) by using the solubility parameter to predict polymer-solvent interactions and then attempting to correlate those interactions with the rate of ink-tack build on coatings containing different latex binders.

Theory

Solubility parameter for latex polymers

Definition. The solubility parameter, δ , is used widely for correlating polymer-solvent interactions. Hildebrand and Scott (7) derived the solubility parameter from the cohesive energy and the heat of mixing and defined it as

$$\delta = (\Delta E/V)^{1/2} \quad (1)$$

where

ΔE = energy of vaporization

V = molar volume.

For relatively simple low-molecular-weight compounds such as sol-

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vents, the solubility parameter is easily calculated from the energy of vaporization or from vapor pressure vs. temperature data.

Since polymers cannot be evaporated, the solubility parameter for a given polymer is estimated using indirect methods. These methods include comparative swelling or dissolving experiments in solvents of known solubility parameters (7). Such experiments were carried out in this work and are discussed later.

From the relationship in Eq. 1, a requirement for high solubility of a polymer, P, in a solvent, S, is that the difference in solubility, $\delta_p - \delta_s$, be as small as possible. Alternatively, an increase in the difference between δ_p and δ_s would indicate a reduced solubility of the latex polymer in the solvent. The present work focused on the effect of increasing the difference between δ_p and δ_s in an effort to reduce the solubility of latex binder in ink solvent.

Effect of chemical structure on δ_p . The solubility of a given polymer in various solvents can be influenced by its chemical structure (7). The solubility parameter for polymers with different hydrocarbon backbones has been calculated based upon the repeating unit in the polymer chain (8). When the polymer contains polar and hydrogen bonding groups, then there are additional contributions to δ_p , so that

$$\delta_p^2 = \delta_b^2 + \delta_p^2 + \delta_h^2 \quad (2)$$

where

δ_b = component for polymer backbone

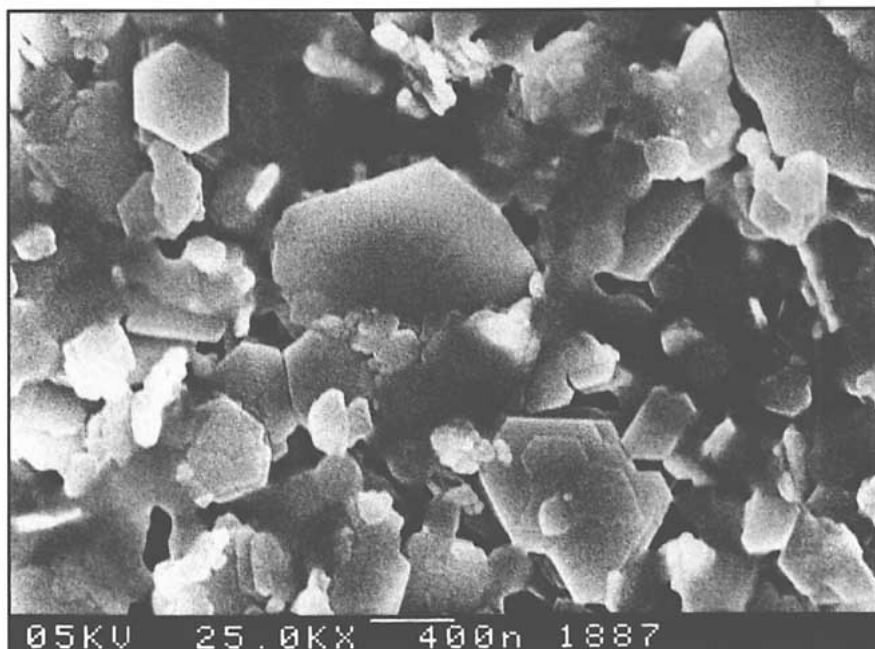
δ_p = component for polarity

δ_h = component for hydrogen bonding.

The solubility of the polymer in a solvent, therefore, is represented by the total of the differences in the solubility parameters for each component:

$$\Delta\delta = [(\delta_{bp} - \delta_{bs})^2 + (\delta_{pp} - \delta_{ps})^2 + (\delta_{hp} - \delta_{hs})^2]^{1/2} \quad (3)$$

3. SEM of coated sheet shows pigment particles covered by a thin film of polymer



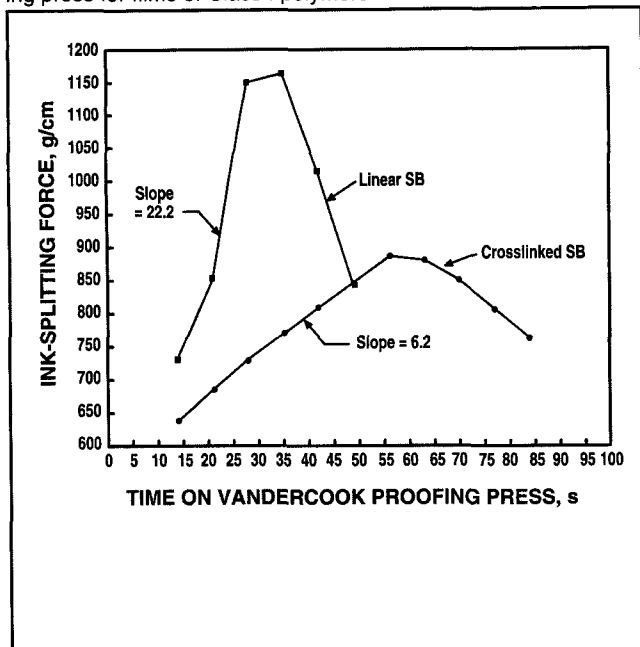
II. Model latex polymers used in laboratory experiments

Class	Surface energy/polarity (X_p)	Gel content, %
Class I		
Constant chemical structure		
Low surface energy/polarity	<0.1	...
Variable physical state		
Linear	...	<40
Crosslinked	...	>80
Class II		
Constant physical state		
Crosslinked polymer	...	>80
Variable chemical structure		
Low surface energy/polarity	<0.1	...
High surface energy/polarity	>0.3	...
Class III		
Constant physical state		
Linear polymer	...	<40
Variable chemical structure		
Low surface energy/polarity	<0.08	...
High surface energy/polarity	>0.20	...

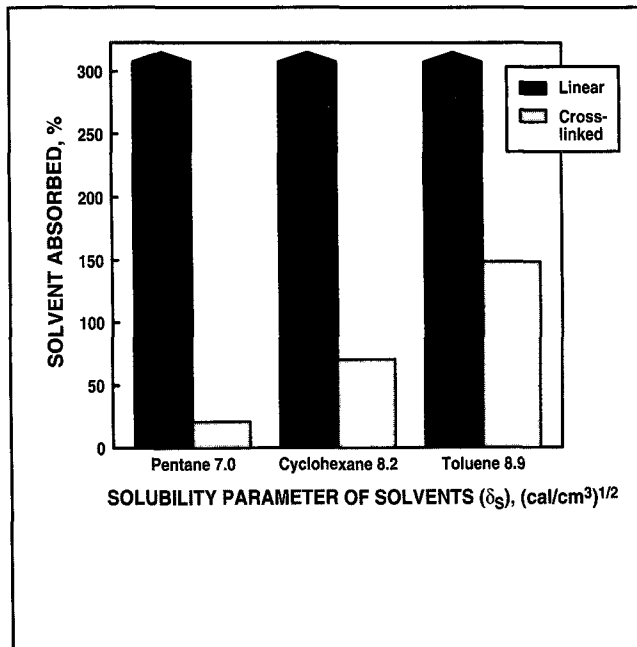
In the literature, it was shown that the solubility parameter of a polymer could be changed significantly, depending on its chemical structure. For example, δ_p for polystyrene is 8.6 (cal/cm³)^{1/2}, while δ_p for polyacry-

lonitrile is 15.4 (cal/cm³)^{1/2}. In this work, the chemical compositions of polymers were changed to increase $\Delta\delta$, the difference between δ_p and δ_s .

4. Ink-splitting force as a function of time on the Vandercook proofing press for films of Class I polymers



5. Solubility of Class I polymers in pentane, cyclohexane, and toluene



III. Coating formulations

Ingredients*	Pigment content, parts/100 parts
Kaolin clay	75.0
Calcium carbonate	25.0
Sodium polyacrylate	0.2
Experimental latexes	14.0
Carboxymethyl cellulose	0.5
Calcium stearate	0.5

*Hydraine® kaolin clay, Hydracarb 90® calcium carbonate, Dispex N-40® sodium polyacrylate, Finfix 5® CMC, Nopcote C-104® calcium stearate

Effect of physical state on δ_p . The physical state of a polymer also can contribute to its solubility properties. For example, Fig. 1 shows that the equilibrium swelling for polystyrene over a range of δ_s is considerably different for linear and crosslinked polystyrene. The linear polymer showed relatively low equilibrium swelling over a certain range of δ_s but became infinitely miscible with the solvent within a different range of δ_s . In contrast, the solubility of the crosslinked polymer increased over a different range of δ_s . However, the crosslinked polymer

never became miscible in the solvent, and it was less soluble than the linear polymer, as indicated by the reduction in swelling for the crosslinked polymer. The maximum in the equilibrium swelling curve for the crosslinked polymer was designated as δ_p for the crosslinked polymer. Thus the linear polymer and the crosslinked polymer had significantly different δ_p .

Based on these factors, the current work focused on the effects of both the physical state and the chemical structure of the polymers on $\Delta\delta$, as represented by Eq. 3.

Experimental

Determination of δ_p

The solubility parameter for the different latex polymers, δ_p , was determined over a range of δ_s [7.0–11.8 (cal/cm³)^{1/2}], as seen in Table I. The δ_s for the offset-ink solvents is in the range of 7.4 to 7.8 (cal/cm³)^{1/2}.

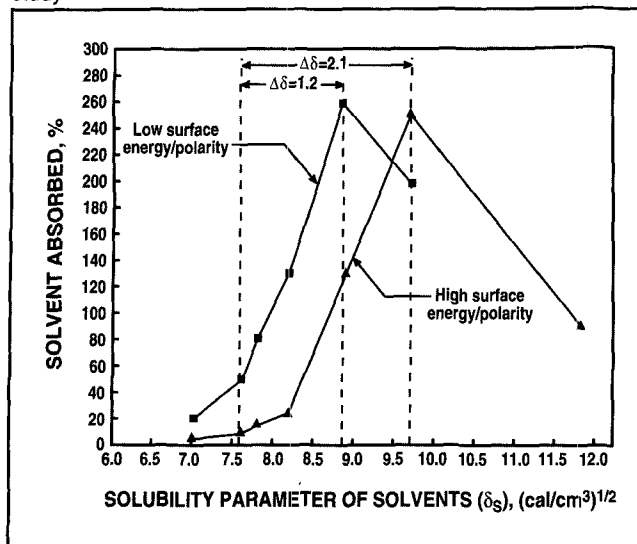
Experiments were carried out to determine the amount of solvent absorbed by the latex film at ambient temperature. The latex film was placed in contact with a solvent for

different lengths of time, and the weight of solvent absorbed by the film was recorded for each time interval. For some latex polymers, the amount of solvent absorbed was so high that the polymer formed a gel and then became miscible in a very short period of time. Other polymers did not absorb very much solvent in the lower δ_s range, with more absorption occurring in the higher range. In such a case, the extent of the solvent absorption was such that the polymer was not completely miscible in the solvent but only formed a gel.

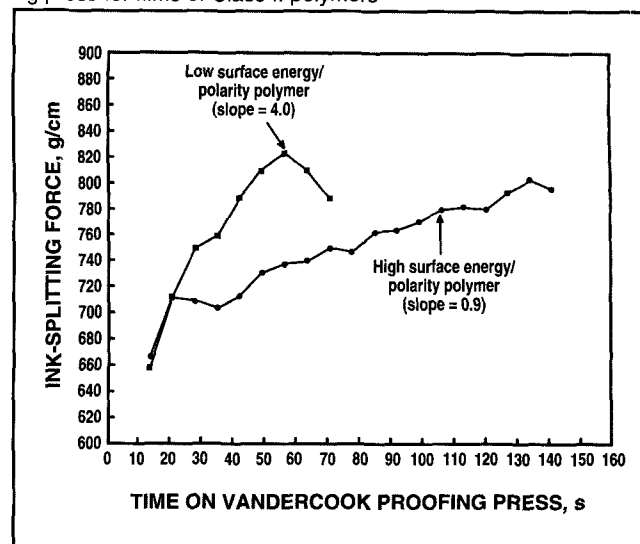
Model latexes

Model latexes with different physical and chemical characteristics were prepared by an emulsion polymerization process. Three classes of model latexes were prepared to examine the effects of physical parameters (linear vs. crosslinked polymer) and chemical parameters (high vs. low surface energy/polarity) on ink-tack build. Within each class, one parameter was held constant, and one parameter was varied.

6. Solubility of Class II polymers over the full range of δ_s used in this study



7. Ink-splitting force as a function of time on the Vandercook proofing press for films of Class II polymers



- Class I polymers—the physical state was varied (linear or crosslinked); the chemical structure was constant (low surface energy/polarity).
- Class II polymers—the chemical structure was varied (low or high surface energy/polarity); the physical state was constant (crosslinked polymer).
- Class III polymers—the chemical structure was varied (low or high surface energy/polarity); the physical state was constant (linear polymer).

The three classes of model latexes are described more thoroughly in Table II.

The polymerization conditions were modified to produce both linear and crosslinked SB latex polymers. The degree of crosslinking was established by determining the toluene-insoluble content (percent gel) of the latex film.

The surface energy/polarity, X_p , of the different latex-polymer films was determined from contact-angle measurements using a contact goniometer, with water and methylene iodide used as testing liquids (9). As in earlier work (9), X_p was determined by calculating the geometric mean.

Coating formulations

Coating formulations were prepared both in the laboratory and on the pilot coater using the following procedure. Dry clay and calcium carbonate were dispersed at 75% solids in water in a tank measuring 43 in. high and 36 in. in diameter. The pigment slurry was agitated for 10 min at 218 rpm and 20 min at 437 rpm. Other ingredients were added in the following order at agitation of 145 rpm: latex, CMC (carboxymethyl cellulose), calcium stearate. The CMC was added as a 10% solution. The latexes were formulated in a total latex coating and are described in Table III.

Laboratory coating. Coatings were prepared on a bench coater at a coat weight of 11 lb/3300 ft² per side. The coated papers were supercalendered at 1200 pli and 67°C using a 1-2-1 nip sequence. Prior to testing, the papers were conditioned for 24 h at 50% R.H. and 21°C.

Pilot coater. Coatings were applied to a groundwood-free surface-sized paper using a flooded-nip-inverted-tube blade on a 28-in.-wide pilot coater running at 2000 ft/min. The paper was coated to a target of 10 lb/3300 ft² per side. All coatings were dried to 4% moisture. The coated papers were supercalen-

dered at 2000 pli and 200°F, four nips per side, at 1500 ft/min. The coated papers were evaluated on a six-color sheet-fed press (after sheeting) or on a six-color web-offset press.

Press conditions

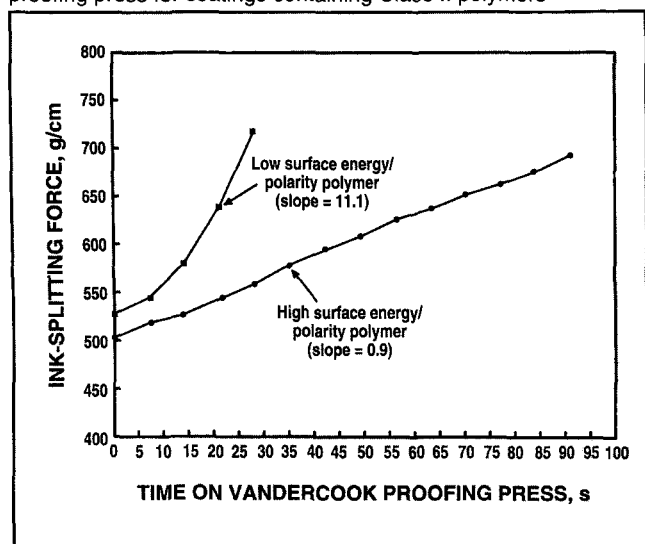
Press speed for the sheet-fed offset press was 7000 impressions per hour. The web offset press was run at 25,000 impressions per hour. Both presses had six color stations, with the colors applied in the following order: black, cyan, magenta, yellow, black, cyan.

Laboratory measurement of ink-tack build

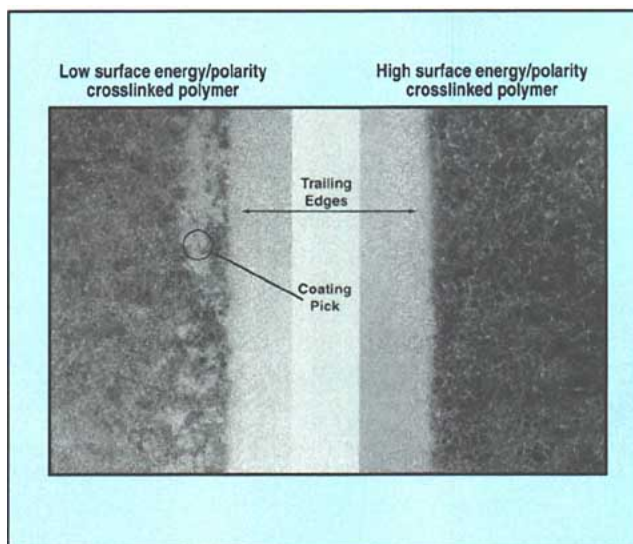
Ink tack on a coated paper can be determined by measuring the splitting force required to release the ink from the blanket on a commercial press. The ink-coating interaction, in turn, can be established by measuring the tack increase at each printing unit (10).

These conditions can be simulated in the laboratory by using a modified Vandercook proofing press (10, 11). The proofing press simultaneously prints the coated paper from a special nonabsorbent blanket and measures the splitting force required

8. Ink-splitting force as a function of time on the Vandercook proofing press for coatings containing Class II polymers



9. Prints from commercial offset press (six-color, sheet-fed) for sheets with coatings containing Class II polymers



to separate the printed sheet from the blanket.

In the test procedure, ink is applied to a precision-ground steel printing block using a scraper. The ink layer on the block is at a specific thickness, and the same amount of ink is metered out each time the test is run. The ink is then transferred to a special nonabsorbent blanket that will not remove the solvent and vehicles from the ink on the Vandercook press. Within the next minute, the block is cleaned and the test paper is attached to the load cell. Printing is then initiated. After the initial print, the press is advanced at intervals of 7 s, causing an ink split between the ink remaining on the blanket and the ink on the coated paper. As the printed sheet is split from the inked blanket, the force of separation is sensed by a load cell and recorded. The test operator observes the inked blanket for signs of coating pick and terminates the test when coating failure is observed on the blanket.

The ink-coating interaction is established by plotting the splitting forces vs. elapsed time on the press. The slope of these plotted data indicates the rate of ink-tack build in units of grams/centimeter/second.

This test also provides the num-

ber of printing impressions the sheet can withstand before coating pick occurs. Historical data have shown that failure of coated paper in four or fewer printing impressions should be of concern, because it usually leads to coating pick on a commercial six-color press. This would depend, of course, on such variables as inks used, press speeds, number of printing units, and temperature. Usually, the greater the number of printing impressions that the coated paper can withstand before coating pick occurs, the less likely it is that a problem will occur on a commercial press.

The data also reveal a relationship between the rate of ink-tack build (slope) and the number of printing impressions before the failure pass. Coated papers with a high rate of ink-tack build typically withstand fewer printing impressions before coating pick occurs, since high values for ink-splitting force are obtained within a short time of testing. In contrast, low-slope papers usually do not show failure until after a greater number of printing impressions.

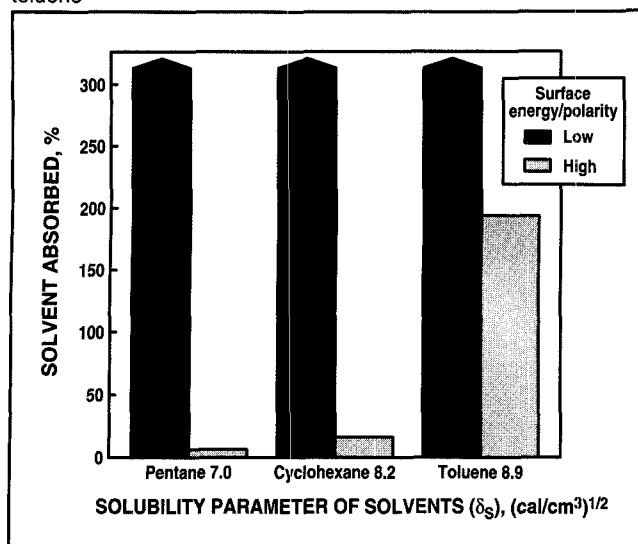
Results and discussion

Class I polymers—effect of physical state on ink-tack build and δ_p

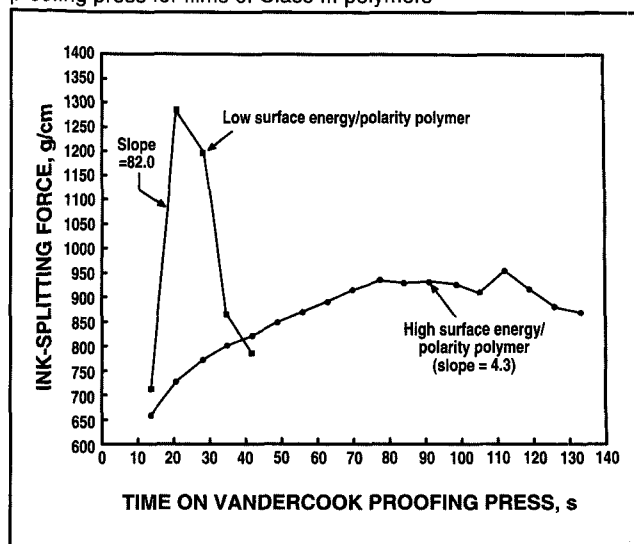
Research by Kelly *et al.* (6) showed that the ink-setting behavior of coated paper was affected by the degree of crosslinking in the latex polymer. In that work, natural latex was selected for a linear polymer, and the level of crosslinking was controlled by sulfur vulcanization. The ink-setting time of the coated paper containing the natural latex was significantly faster than that of the vulcanized natural latex (20 s vs. 40 s, respectively).

In the current work, the physical state of the polymers, i.e., linearity vs. crosslinking, was investigated using the Class I polymers from the model latex series described in Table II. Polymerization conditions were modified to produce the two physical states. The level of toluene-insoluble content was used to indicate the extent of crosslinking. The SB latex polymer with a low gel content was referred to as a linear polymer, while the polymer with a high gel content was designated as crosslinked. Both versions were comparable in particle size and vinyl acid level of the polymer.

10. Solubility of Class III polymers in pentane, cyclohexane, and toluene



11. Ink-splitting force as a function of time on the Vandercook proofing press for films of Class III polymers



Ink-coating interaction. The Vandercook proofing press test method was used to investigate the interaction of the two coatings with the ink. As seen in Fig. 2, there were significant differences in the ink-coating interaction for the two latex coatings.

The ink-splitting force increased extremely rapidly for the coating containing the linear SB, with ink tack increasing at the rate of 29.8 g/cm/s. This coating underwent coating pick after only two printing impressions. Such a fast rate of tack build would likely result in coating pick on a six-color commercial press.

The coating containing the crosslinked SB showed a much slower increase in the splitting force, with ink tack increasing at the rate of 7.8 g/cm/s. This coating also withstood eight printing impressions before experiencing pick. It is unlikely that coating pick would occur on a commercial press with this type of ink-coating interaction.

These findings are in agreement with the findings of Kelly *et al.* (6) regarding the effect of linear and crosslinked latex polymers on ink setting times.

Ink-latex-film interaction. Results obtained by Kelly *et al.* (6) also suggested that the ink-setting be-

havior of the coatings correlated to the extent of interactivity between the latex polymer and the ink solvent. Using SB latex polymers with different reactive groups, they determined both the percent solvent absorbed and the percent linear increase of the polymer film in the litho ink solvent. A latex coating with a relatively long ink-setting time had a relatively low linear increase of the film in the solvent. In contrast, a coating with a short ink-setting time contained a latex that had a higher linear increase of the film in the solvent. This interactivity would seem reasonable, since the scanning electron micrographs (SEM) of coating surfaces at high magnification in the present work showed that the pigment particles were covered with a film of latex polymer, as seen in Fig. 3.

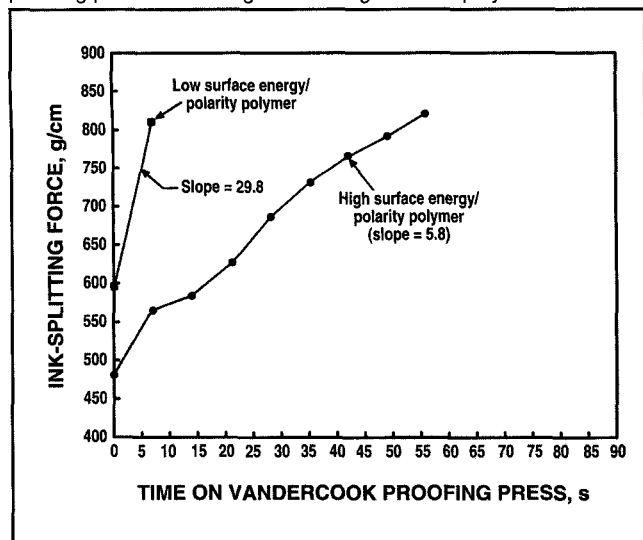
The latex-film-ink interaction was determined for both the linear and crosslinked polymers in the present study. A commercial, fast-setting cyan ink (designed for use on sheet-fed presses) was used in tests on the modified Vandercook proofing press. Ink-splitting force was measured at 7-s intervals.

The plot of ink-splitting force vs. printing-press time in Fig. 4 shows that the linear SB polymer film was

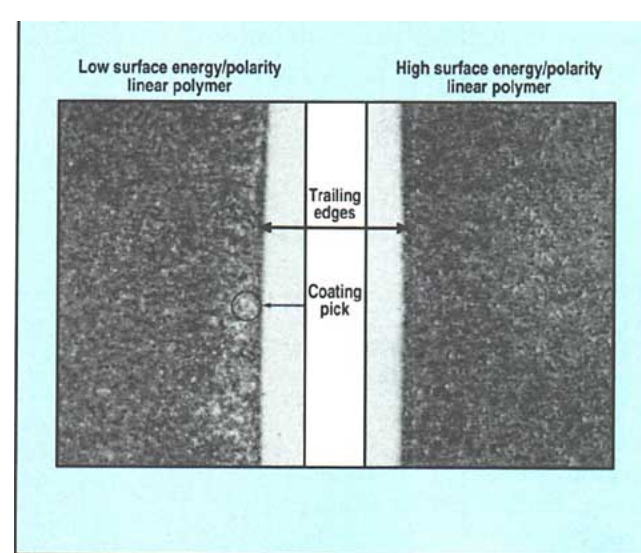
significantly more interactive with ink than that of the crosslinked version. For the linear SB polymer, ink-splitting force increased rapidly at a rate of 22.2 g/cm/s, reached a maximum splitting force, and then decreased. The decrease in force reflects the drop in tack as the ink sets. In contrast, the ink-splitting force for the crosslinked polymer increased at a lower rate of 6.2 g/cm/s. The slower rate of increase for the crosslinked polymer also extended the time required to reach the maximum in tack level, i.e., the ink-setting time. The time required for the ink to set was 55 s for the crosslinked polymer, compared with 25 s for the linear polymer.

Latex δ_p . The significant differences in the ink-latex-film interactivity for the two polymers led to speculation that the interactivity might be linked to the polymer's solubility characteristics in the ink solvent. It was decided, therefore, to determine the solubility of the polymers in a variety of solvents, including solvents used in commercial printing inks. The solubility parameters for the solvents ranged from $\delta_s = 7.0$ (cal/cm³)^{1/2} for pentane to $\delta_s = 11.8$ (cal/cm³)^{1/2} for acetonitrile. Table I lists all of the solvents and their associated δ_s .

12. Ink-splitting force as a function of time on the Vandercook proofing press for coatings containing Class III polymers



13. Prints from commercial offset press (six-color, sheet-fed) for sheets with coatings containing Class III polymers



The amount of solvent taken up by each of the latex polymers was measured as a function of δ_s , which was useful in estimating $\Delta\delta$, the difference between δ_p and δ_s . This difference was interpreted to be primarily from the physical state of the polymers (crosslinked vs. linear), since the chemical compositions (low surface energy/polarity) were comparable.

The linear SB latex polymer from the Class I polymers absorbed a very high level of solvent and was miscible from pentane [$\delta_s = 7.0$ (cal/cm³)^{1/2}] to cyclohexane [$\delta_s = 8.2$ (cal/cm³)^{1/2}], as seen in Fig. 5. This solubility parameter range included that of the offset-ink solvents [$\delta_s = 7.4$ – 7.8 (cal/cm³)^{1/2}]. In contrast, the crosslinked polymer film was affected to a much lesser extent by pentane and cyclohexane. The crosslinked polymer film absorbed somewhat higher levels of the toluene solvent [$\delta_s = 8.9$ (cal/cm³)^{1/2}]. In other words, $\Delta\delta$ was greater for the crosslinked polymer than for the linear polymer (1.9 vs. 0). The higher $\Delta\delta$ for the crosslinked SB polymer indicated that the polymer was less soluble in an ink solvent system than the linear version. The higher $\Delta\delta$ also correlated to the differences in the rate of ink-tack build on both films and coatings.

Class II polymers—effect of chemical structure on ink-tack build and δ_p

An investigation was carried out to determine whether modification of the latex polymer's chemical structure (surface energy/polarity) could significantly affect δ_p . If $\Delta\delta$ could be increased, then the rate of ink-tack build might decrease, allowing a higher number of printing impressions before coating failure.

The surface energy/polarity of a given polymer is dependent on its composition. In previous work, the surface energy/polarity for the polymers ranged from a low of $X_p = 0.014$ to a high of $X_p = 0.234$ (9). Surface energy/polarity for the various polymers was determined by measuring contact angle using water and methylene iodide as test fluids. The Class II (crosslinked) polymers used in the current work were produced at two levels of surface energy/polarity, with $X_p > 0.3$ representing a high surface energy/polarity and $X_p < 0.1$ representing a low surface energy/polarity.

Latex δ_p . The solubility of the Class II latex polymers is plotted as a function of δ_s in Fig. 6. For both polymers, δ_p was defined as the point of maximum solvent absorption. The

polymer with high surface energy/polarity had a much higher solubility parameter ($\delta_p = 9.7$) than the low-surface-energy polymer ($\delta_p = 8.8$). Using a solubility parameter of 7.6 (cal/cm³)^{1/2} for the solvent in the commercial, fast-setting cyan ink, $\Delta\delta$ was 2.1 for the high-surface-energy/polarity polymer, compared with 1.2 for the low-surface-energy polymer. Figure 6 also shows that there was significantly less solvent absorption by the high-surface-energy/polarity polymer in the ink-solvent region of $\delta_s = 7.4$ – 7.8 . It should be noted that at the maximum solvent absorption, both of the polymers were gel, indicating that neither was entirely miscible in the solvents.

Ink-latex-film interaction. Having established the different δ_p for the high- and low-surface-energy/polarity polymers, the next step was to investigate the rate of ink-tack build on latex films.

The rate of increase for ink-splitting force was significantly slower for the higher-surface-energy/polarity polymer film than the low-energy control (0.9 g/cm/s vs. 4.0 g/cm/s), as seen in Fig. 7. In fact, the rate of increase for ink-splitting force on the high-surface-energy film had not yet reached a maximum at the end

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of the testing time (140 s). In contrast, the low-surface-energy control polymer film interacted with the solvent in the ink to a much higher extent, and the ink reached its setpoint after 56 s. This slower rate of ink-tack build of the ink on the high-surface-energy/polarity latex film was related to its reduced solubility in the ink solvent.

Ink-coating interaction. The rate of ink-tack build on pigmented latex coatings also was determined. Figure 8 shows the rate of increase for the ink-splitting force vs. the printing-press time of interaction between the ink and the coating. The trend is similar to that of the latex films in Fig. 7. With the paper coating containing the higher-surface-energy/polarity polymer, the rate of increase for ink-splitting force was significantly slower (4.0 g/cm/s) than that of the low-surface-energy version (11.1 g/cm/s). As a result, the coating containing the high-surface-energy polymer did not fail until 14 printing impressions, compared with 5 impressions for the control coating.

Changing the latex polymer's δ_p so that it was further away from the ink solvent's δ_s reduced the polymer's interaction with the ink. The result was a lower rate of ink-tack build on the pigmented latex coating.

Runnability on a commercial, six-color, sheet-fed offset press. Based on these results, it was decided to evaluate the two latex polymers in coatings on a commercial, six-color, sheet-fed offset press.

As described previously (2), if the tack of the ink printed in the early color stations increases too rapidly, there is usually coating pick when the tacky ink layer splits away from the printing blankets in the later color stations. In such cases, the splitting force between the inked blanket and the ink layer on the coating exceeds the strength of the coating. The result is contamination of

the blanket surface with coating particles and, eventually, press shutdown for blanket cleanup.

On the six-color sheet-fed press, the coating containing the high-surface-energy/polarity latex polymer printed without any indication of coating pick, while the control coating with the low-surface energy polymer showed significant picking. Figure 9 presents photographs of printed surfaces from both sheets. In particular, the later blankets on the press had considerable buildup of coating specks while running the coating containing the low-surface-energy polymer.

Class III polymers—effect of chemical structure on ink-tack build and δ_p

The results for the Class I polymers showed that coatings containing linear latex polymers had a faster rate of ink-tack build than coatings containing highly crosslinked polymers, resulting in coating pick within a fewer number of printing impressions. However, previous work indicates that the blister resistance of web-offset coatings is improved when linear or low-gel-content latex polymers are used in the coatings (12–15).

Results with the Class I and Class II latex polymers led to further work with linear polymers. The main purpose of the work was to determine if δ_p of a linear polymer could be increased above the δ_s of the ink solvent to obtain a sufficiently large $\Delta\delta$. If so, then the rate of ink-tack build of the ink with the latex-polymer film and, correspondingly, with the coating should be reduced. The coating would then be able to withstand more printing impressions, and the coating pick in a commercial web-offset press could be minimized.

The two Class III polymers that were used in this portion of the work were both linear but had either low or high surface energy/polarity.

Polymer δ_p . Solubility of the Class III polymers was measured in solvents over a range of δ_s . The high-surface-energy/polarity linear polymer absorbed significantly less n-pentane ($\delta_s = 7.0$) and cyclohexane ($\delta_s = 8.2$) than the low-surface-energy/polarity linear polymer, as seen in Fig. 10. In fact, the linear low-surface-energy/polarity polymer was miscible with solvents in the range of $\delta_s = 7.0$ – 8.2 (cal/cm³)^{1/2}. As shown in Fig. 10, the high-surface-energy/polarity polymer was relatively insensitive to the solvents in this range of δ_s , which includes that of the ink solvents.

Ink-latex-film interaction. Correspondingly, the linear high-surface-energy/polarity polymer film showed a significantly lower rate of ink-tack build or slope than the low-energy version (4.3 g/cm/s vs. 82.0 g/cm/s, respectively), as seen in Fig. 11. The ink on the low version was set within a relatively short time (20 s), while the ink on the high version took a much longer time to set (>100 s).

Ink-coating interaction. The coating containing the linear high-surface-energy/polarity latex polymer also was less interactive with the ink, with a rate of ink-tack build of 5.8 g/cm/s compared with 29.8 g/cm/s for the coating containing the low-surface energy polymer. The results are illustrated in Fig. 12. The number of printing impressions to coating pick was also higher for the coating containing the high-surface-energy polymer (9 vs. 2).

Runnability on a commercial, six-color, sheet-fed offset press. Coatings containing these linear polymers were evaluated on a commercial, six-color, web-offset printing press. The coating containing the high-surface-energy/polarity polymer ran on the press cleanly, while the low version resulted in considerable coating pick, as seen in Fig. 13.

In addition, the coatings containing these linear (low gel) latex poly-

mers showed superior blister resistance compared with that of the crosslinked (high gel) control. For both the high- and low-surface-energy linear latex polymers, there was no blistering detected on the commercial, six-color, web-offset press at a web-exit temperature of 375°F. In contrast, the control coating containing a crosslinked (high gel) latex polymer blistered at a web-exit temperature of 265°F. The coatings were comparable in coat weight (10 lb/3300 ft² per side) and moisture level at the press (4.0–4.5%, determined via TAPPI Test Method T 412 om-90). These results confirmed earlier results demonstrating the superior blister resistance of low-gel latex polymers.

Conclusions

Efforts to reduce coating pick in demanding printing applications led to a study of the interaction between latex polymers in the coatings and the solvents in the offset inks. The study revealed the following:

1. The degree of solubility of the latex polymer in ink solvents had a significant effect on the rate of ink-tack build for latex films and coatings and on the number of printing impressions to coating pick.
2. Both the physical state (linear vs. crosslinked) and the chemical structure (low vs. high surface energy/polarity) of the latex polymer influenced its solubility parameter and the corresponding ink-coating interactions.

3. Linear SB latex polymers were more interactive with the offset inks than the crosslinked versions. Correspondingly, the rate of ink-tack build for the linear polymers was significantly higher than that of the crosslinked polymers, and the number of printing impressions to coating pick was lower.
4. Modifying the crosslinked latex polymer to a higher level of surface energy/polarity increased the difference between its solubility parameter and that of the ink solvents. The modified polymer thus showed less interactivity with the ink, a correspondingly lower rate of tack-build in the coatings, and more printing impressions before coating pick occurred. Results on a commercial, six-color, sheet-fed printing press confirmed that this type of polymer provided greater resistance to coating pick.
5. Modifying the linear latex polymers to a higher level of surface energy/polarity had a similar effect. Coatings containing these modified linear latex polymers showed superior blister resistance on a commercial, six-color, web-offset press without the occurrence of coating pick. **■**

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