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Deposition of Hot Melt and Wax on Surfaces

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Abstract

Polyvinyl acetate (PVAc) injected into water stirring in a Britt jar partially deposits on the blade. The degree of deposition decreases with increasing temperature and with decreasing molecular weight, probably because of decreasing viscosity. The deposition tendencies of PVAc mixtures tend to be intermediate between those of their components. In contrast, wax deposits on the walls of the Britt jar, possibly because the surface area of the wall exceeds that of the blade, and deposition occurs on the first surface that the wax encounters. Mixtures of wax and PVAc exhibit a complex range of behavior; e.g. wax enhances the blade deposition of a low-molecular PVAc by increasing the viscosity of the mixture. Fiber has a conflicting effect on blade deposition. On the one hand, it can add "body" to low-viscosity stickies, thereby increasing its resistance to washout; on the other, it can act as a scouring agent. Deposition of PVAc to the blade from whitewater or water containing surfactant was similar to that from water.

Introduction

The deposition of stickies and waxes on surfaces depends on factors such as the physical and chemical nature of the contaminant, the effect of other chemicals present, the nature of the surface, and operating conditions such as temperature and shear (1-11). Identifying some of these factors is important, even if it only serves to recognize problem situations, or regions in the mill that may be especially prone to stickie deposition. During previous Britt jar work on the interactions among hot melt, fiber and water (12), we noted that a portion of the stickie in the system occasionally deposited on the blade. We have studied the effect of temperature, hot melt type and composition, consistency, and surface properties on deposition, and in this paper we identify some of the conditions that promote the attachment of wax and stickies to surfaces.

Experimental

Our general experimental protocol for the hot melts was to slowly inject a 2% solution of polyvinyl acetate, PVAc (obtained from Aldrich or Polyscience), in methanol to 600 mL of either water or a pulp suspension stirred at 200-800 rpm at a pre-set temperature in a Britt jar. Reynolds numbers at 200, 400, 600, and 800 rpm were 3.94E3, 7.89E3, 1.18E4, and 1.58E4, respectively. The PVAc drops out of solution upon addition to water, and any attachment to the blade or the sides of the container occurs rapidly. The mixture is stirred for 15 minutes, the water discarded, and the deposits scraped off the surface, dried, and weighed. All measurements were made at least in duplicate, and the uncertainty was typically of the order of 10-30%, although higher variability was observed on occasion. Hence, the results should only be considered as semi-quantitative.

Deposition of stickies on surfaces in the absence of fiber

Pure PVAc

Deposition of PVAc increases with increasing molecular weight as shown in Figures 1 and 2, since the viscosity increases concurrently, and the more viscous material resists washout from the blade. Most of the variability in temperature and rpm in Figures 1 and 2 can be reconciled through consideration of PVAc viscosity. Since increasing temperature lowers viscosity, deposition is either unaffected by, or decreases with increasing temperature. Back previously identified viscosity as a major factor that determines the extent to which stickies can be sheared off surfaces (10-13). He showed that pitch deposits from a sulfite pulp decreased with increasing temperature as a result of reduced pitch viscosity (13).

The effect of stirring speed is straightforward for the MW 12,800 material in that the higher speed increases the washout tendency. Deposition of this polymer is low to begin with, and it remains mostly in the aqueous suspension. The MW 90,000 polymer exhibits more complex behavior, rising between 400 and 600 rpm, but decreasing on either side of the 600 rpm value in Figure 1. The effect was reproducible. Back (13) noted a similar effect with pitch. Presumably, the influence of washout increases at higher rotational speeds. Substantial quantities of the MW 500,000 attach to the blade under all conditions, probably because its higher viscosity enhances its resistance to washout. In summary, a low molecular weight stickie tends to stay in suspension, whereas increasing viscosity increases the degree of deposition on the blade.

In order to determine the extent to which the blade material influences deposition, the metal blade of the Britt jar was substituted with one that was Teflon-coated. The blade assembly consists of three circular paddles connected to a shaft. The metal paddles were of 1.96" diameter; the Teflon ones were of 2.00". Hence, the Reynolds numbers were marginally higher for the Teflon blades. In general, deposition was lower on Teflon as shown by the comparison in Table 1; this trend is reasonable since stickies should be attracted less to Teflon than to metal.

Mixtures of PVAcs

Since pure stickies are rarely found beyond the initial repulping operation (14, 15), measurements were made with mixtures of two stickies, which were prepared together in methanol and then added to the Britt jar. The results are presented in Figures 3-5. For example, Figure 3 presents data on mixtures of the MW 12,800 polymer with either the MW 90,000 material or the MW 500,000 stickie. Except for one case, the 90,000 and 500,000 mixture at 400 rpm in Figure 5, deposition decreases with temperature. Again, the effect of stirring speed alone is uncertain, with no clear trend emerging. However, the overall trend is for the property of the PVAc mixture to be intermediate between those of its constituents.

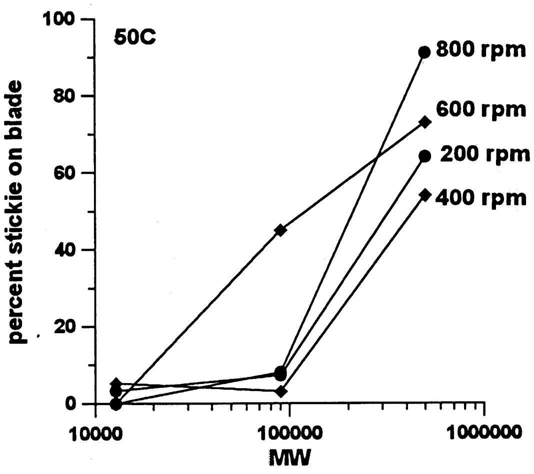

Figure 1: Stickie deposition at 50°C

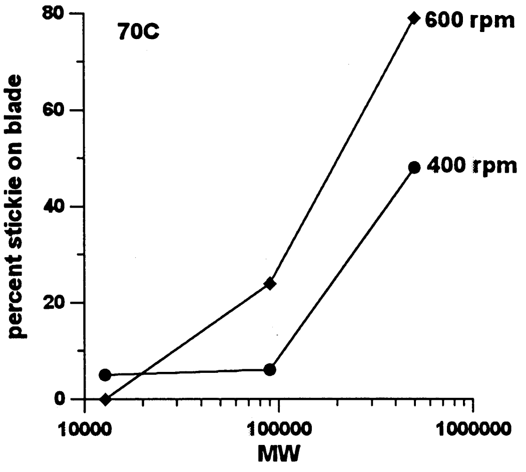

Figure 2: Stickie deposition at 70°C

Table 1: Deposition of PVAc on the Britt jar blade (50°C)			
MW	rpm	avg. percent stickie on blade	
		Teflon	metal
12,800	400	0	5.3
	600	5.0	0
90,000	400	2.7	3.1
	600	4.9	45
500,000	400	9.5	54
	600	8.2	73

While this is not true for all mixtures (as will be shown later for wax), it seems that the deposition properties of PVAc with components of different degrees of polymerization can be tailored through mixing. For example, the properties of a MW 90,000 polymer can be approximated by a mixture of MW 12,800 and MW 500,000 polymers.

Each pair of stickies used above was dissolved in methanol, and was, therefore, completely mixed when it deposited out of solution upon addition to water. Conceivably, separate addition of the stickies to the solution could alter deposition behavior, e.g., one stickie could attach to the blade first, with the other then depositing on the attached stickie. In order to resolve this issue, 0.1 g of each PVAC dissolved in 10 mL of methanol was added sequentially to water in the Britt jar kept at 50°C with the rotor set at 400 rpm. Deposition was found to be independent of the sequence of addition, confirming that the results are not an artifact of the mode of addition.

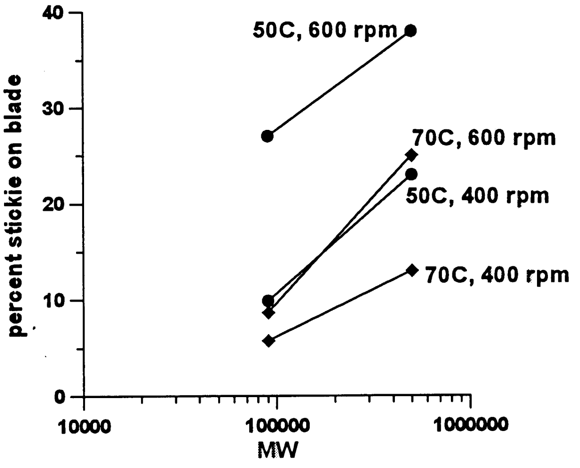

Figure 3: Deposition of MW 12,800 and (MW 90,000 or MW 500,000)

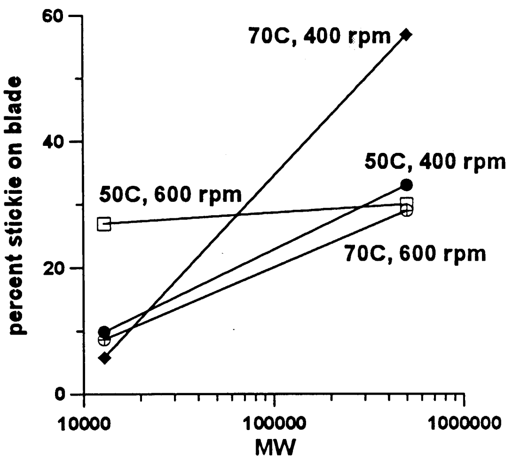

Figure 4: Deposition of MW 90,000 and (MW 12,800 or MW 500,000)

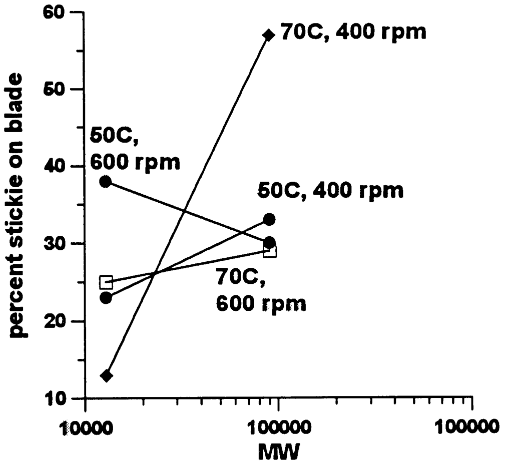

Figure 5: Deposition of MW 500,000 and (MW 12,800 or MW 90,000)

Wax

The above approach was extended to 3040 Amber wax (used in curtain coating), 1 g. of which was melted and added to water in the Britt jar. The wax was obtained from Astor Corporation, and had a nominal melting point of 54°C. In contrast to the PVAc work, most of the wax was found on the baffles and walls of the container. Some material was also attached to the impeller shaft at the air:water interface. We reason that the wax attaches to the first receptive surface that it encounters, and resists washout. Since the area of the wall greatly exceeds that of the blade, the wax preferentially deposits there. Similar results were observed by Back (13) who observed that viscosity played opposing roles in pitch deposition.

On the one hand, low resin viscosity facilitates deposition; on the other, it promotes washout.

Mixtures of wax and PVAc were studied next in order to determine the extent to which PVAc modified the behavior of wax. Equal amounts (0.5 g.) of wax and PVAc were melted together and added to water in the Britt jar and processed for 15 minutes. The results shown in Table 2 demonstrate complex behavior. For example, blade deposition of either pure wax or the MW 12,800 PVAc alone is small, whereas a substantial amount of a mixture of the two attaches to the blade at 400 rpm and 50°C. Presumably, the wax raises the viscosity of the mixture to the point where it can both deposit on the blade and resist washout. Blade deposition of the MW 500,000 material is reduced in the presence of wax, probably because the mixture resembles wax more than it does the PVAc. The important point is that unlike mixtures of PVAc, the properties of wax-PVAc mixtures are not necessarily intermediate between those of its components.

Deposition of stickies on surfaces in the presence of fiber

Stickie attached to fiber

PVAc (1 g.) was melted on different amounts of linerboard, and the material was slushed with 1L of water in a British disintegrator. The pulp (300 mL) was diluted with an equal volume of water and processed in the Britt jar at 50°C for 15 minutes. The material on the blade was then dried and weighed, and the results are presented in Table 3. Deposition of the 12,800 material increases slightly with increasing fiber content. For example, Figure 1 shows no deposition at 50°C at 600 rpm in the absence of fiber, whereas appreciable amounts are found on the blade in Table 3 at the higher consistencies. We attribute the difference to the fact that the fiber adds "body" to the stickie, in effect increasing its viscosity.

Table 2: Deposition of wax/PVAc

MW of PVAC mixed with wax	rpm	temp (°C)	avg. percent wax on blade	avg. percent wax on sides
12,800	400	50	21	30
	600	50	1.6	32
	400	70	1.9	10
	600	70	2.9	18
90,000	400	50	2.7	11
	600	50	13	50
	400	70	1.2	67
	600	70	0.5	10
500,000	400	50	4.2	13
	600	50	1.6	28
	400	70	0.5	22
	600	70	0.2	18

In other words, when the fiber-stickie aggregate contacts the blade, the stickie bonds to the blade, and the fiber provides resistance to washout.

Deposition of the MW 500,000 molecular weight polymer is reduced in the presence of fiber. This polymer has a sufficiently high viscosity to withstand shear, and the added fiber only serves to scour the stickie off the blade. The behavior of the MW 90,000 polymer is inconsistent. Under some conditions, the fiber induces greater deposition; in others the amount is reduced. Highly variable behavior was also observed with this polymer in the absence of fiber (Figure 1). It seems that the fiber can exhibit conflicting behavior. It can reinforce the deposition of low-viscosity materials by providing body. It can also reduce the deposition of more viscous polymers through its scouring action.

Table 3: Deposition of PVAc at 50°C in the presence of fiber

consistency (%)	rpm	percent stickie on blade		
		12,800	90,000	500,000
0.025	400		17	
	600	0	71	0
0.05	400	0	0	
	600	9.9	118	0
0.1	400	0	0	0
	600	0	0	0
0.2	400	14	0	0
	600	20	11	42
0.3	400	18	0	0
	600	1.3	23	0
0.4	400	2.6	0	0
	600	2.9	34	0
0.5	400	5.0	0	0
	600	18	0	0
0.6	400	8.2	0	0
	600	6.4	0	0

Table 4: Effect of consistency on the blade deposition of PVAc

PVAc MW	rpm	average percent stickie on blade consistency (%)			
		0.033	0.067	0.133	0.25
12,800	400	0	0.0046	0	0
12,800	600	0	0	0	0
90,000	400	6.6	0.0141	0.0032	0.0043
90,000	600	7.0	0	0	0
500,000	400	5.1	0.0647	0.0079	0.0055
500,000	600	9.9	0.0455	0	0

Stickie free from fiber

In order to isolate the scouring effect, measurements were made where the stickie was added to a pulp suspension. PVAc (0.2 g.) in 10 mL of methanol was added dropwise to a 600 mL pulp suspension in a Britt jar at 50°C. The mixture was stirred for 15 minutes and the material deposited on the blade was weighed. Although stickies comprised most of the deposits, fiber was also trapped on the blade. The deposits were dissolved in methanol, filtered to remove fiber, dried, and the recovered residue reweighed to give the stickies content. The results listed in Table 4 show that even at low consistency, the amount deposited is decreased substantially from the "no-fiber" results in Figures 1 and 2. The effect is particularly strong for the MW 500,000 PVAc. The most likely explanation lies in the abrasive nature of the fiber referred to above.

Effect of surfactant on blade deposition of PVAc

Inclusion of BRD2360 (a blend of fatty acids sold by Buckman as a flotation aid for secondary fiber recovery) at 0.07 g/L in the Britt jar water did not materially alter deposition as shown in Table 5. In order to determine whether surfactant hydrophibicity played a role, a set of surfactants of different LHB values were obtained from ICI. A material with an LHB value of 2 was prepared from 8% Span 80 (sorbitan monooleate) and 92% of Span 85 (sorbitan trioleate). An LHB 16 material was prepared by mixing 60% of Tween 20 and 40% of Tween 80. The surfactant (0.04 g.) was added to water (50°C) before introduction of the 90,000 PVAc. The deposition appears to be independent of stickie hydrophobicity. Measurements were also made with MW 90,000 PVAc and filtered whitewater from Riverwood International's coated board and linerboard lines at Macon, GA. These results are included in Table 5, and indicate no major changes from the distilled water values. Hence, our results in water should apply, at least qualitatively, to a mill situation. We caution that these results only apply to PVAc, and should not be generalized across all stickies.

Conclusions

Stickies tend to deposit on a surface on account of its hydrophobicity, but washout increases with increasing shear. Fiber can accelerate washout through physical abrasion, although it can also reinforce deposition of a low-viscosity PVAc by strengthening its mat structure. Hence, for deposition to occur, the stickie must bind strongly to the surface and also have a high enough viscosity to resist washout. Since a low molecular weight stickie will usually be of low viscosity, it will tend to be washed out. On the other hand, the softening point of a material may be higher than the system temperature, in which case it may not have enough tack to attach to a surface.

While it is certainly possible for a single stickie to have optimal properties for deposition, it is more likely that these properties can be reached through mixtures. Stickie depositsin mills will usually be comprised of mixtures (14, 15). This could explain why stickie outbreaks in mills occur suddenly and are usually difficult to trace back to a particular load of furnish. Our findings suggest that a contaminant may induce stickie deposition by reinforcing the tack or viscosity of the stickie by mixing with it. Hence, it could induce deposition while only being present in small proportions.

Table 5: PVAc deposition in the presence of surfactant and in whitewater at 50°C

PVAc MW	rpm	average percent stickie on blade		
		control[1]	with surfactant	whitewater
90,000	200	7	11	
90,000	400	3	10	20
90,000	600	45	11	22
500,000	400	54	92	
500,000	600	73	80	

[1] no surfactant

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