The role of specific gravity for removal of hot melt adhesives in recyclable grades

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ABSTRACT: Use of hot melt adhesives with specific gravities outside the range of 0.980 –1.050 allows a mill with forward and reverse cleaners to remove over 90% of hot melt contamination in one pass.

KEYWORDS: Adhesives, density, hot melts, impurities, recycling, removal, stickies, waste disposal.

Stickies are generally any material in pulp being made into paper which exhibits tack on the paper machine. Removal of stickies from recycle fibers is a major problem for recyclers. Millions of dollars are spent for cleaners, screens, dispergers, and various other devices to remove these contaminants from the recycling stream.

This study only addresses hot melt adhesives as a contaminant because of their predominance in the recycle stream and the concomitant problems they cause. The results may also apply to other contaminants such as certain inks, pressure sensitive adhesives, coatings, etc. provided the contaminant does not break up into fine particles that can be held in suspension.

Alternate approach

The adhesive industry has spent much time and money in attempts to develop a repulpable hot melt adhesive. A repulpable adhesive would dissolve in the pulping process and not cause tackiness in a resulting paper sheet. There are still many problems with this concept, however. Questionable areas include the effects on COD, action as a debonding agent to the fibers, buildup in the system, cost, and the tendency of alum and retention aids to reflocculate these materials into tacky buildups. A repulpable hot melt adhesive could conceivably cause more problems than it solves. We therefore propose an alternate approach to make adhesive materials in paper more recyclable by facilitating their easy removability rather than their repulpability.

There are two ways to remove contaminants from fibers during recycling based on size or density. Significant amounts of contamination can be removed by screening. Many adhesives pose a problem for removal in this manner. Typically a pulping and cleaning system is maintained at 120–140°F for best efficiency. At this temperature, many contaminants including adhesives soften enough so that a large contaminant can be forced through a small opening in a screen. The greater the pressure drop across the screen, the more contaminants will be forced into the accept stream. Obviously any contaminant that is smaller than the screen aperture will pass through the screen with the accepts. Small contaminants can form deposits that grow in the system and eventually break off and become lodged in the sheet or even cause a break in the sheet.

The other method of contaminant removal is based on the difference in density between water and the contaminant. The fiber is saturated with water and has essentially the same specific gravity or density as water. A centrifugal cleaner operates by swirling material so that anything heavier than water is forced to the outside and anything lighter than water is thrust to the inside. The inner or outer portions can be removed taking contaminants with them.

Laboratory trials

Our initial premise was that the efficiency of the cleaner must be based on the magnitude of the difference in specific gravity between the contaminant and water. To evaluate this effect, we developed an experimental design and ran several trials in our pilot plant using selected hot melt adhesives.

Quantifying contamination

Doshi *et al.*[1] outline the method we used to detect and quantify sticky contaminants in recycle pulp.

One gram (o.d.) handsheets were prepared from the stock and air dried. After drying, each handsheet was placed between two clean 18.5-cm filter papers and "hot pressed" using a heated laboratory hydraulic press. The platens were heated to and maintained at 350°F. The pressure was held constant at 350 psi. Pressing time was 90 seconds. The sheet was then removed from

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[1]Doshi, M.R., Dyer, J.M., and Krueger, W.C., Pulp and Paper, 58(3): 1984(113).

the press and, while still hot, quickly separated from the filter papers to prevent sticking and fiber tear.

One of the two filter papers was then examined under ultraviolet light, and the number and area of each fluorescent spot was determined using a scaling system similar to that used in the TAPPI Dirt Estimation Chart[2]. Several sheets were made and counted for each sample. The total contaminant area in mm^2 was then tabulated for each sample set. A "stickie factor" (mm^2/g o.d. pulp) was next calculated by dividing the total area (mm^2) of contaminants by the total weight of the handsheets in each set. Calculation of removal efficiency for each hot melt for each cleaning trial was according to Eq. 1.

$$\text{Removal Efficiency\%} = 100\text{x}\,\frac{\text{SF(Feed)} - \text{SF(Accepts)}}{\text{SF(Feed)}} \qquad (1)$$

where

SF(Feed) = stickie factor of the feed

SF(Accepts) = stickie factor of the accepts

Stock preparation

To avoid contaminants present in recycled fiber, a virgin linerboard was initially used as the basestock for our cleaning trials. A desire to produce handsheets viewable without the aid of ultraviolet light initiated a switch to solid bleached sulfate (SBS). In conjunction with the bleached pulp, the hot melt adhesives were dyed using FD&C Violet No. 2 powder dye resulting in handsheets with contaminants readily visible under normal lighting conditions. This also allowed for easy measurement with an image analyzer.

For each cleaner run, 2.4 kg of fiber was repulped using a laboratory hydrapulper. The pulping was done at 2–3% consistency. The stock was then diluted to a final consistency of 0.7%. The total volume for each cleaner run was 80 gal.

[2]TAPPI T 213 om-89 "Dirt in pulp".

Contamination preparation

For our trials, adhesives from two commercial manufacturers of hot melts were selected with a wide range of specific gravities. To prepare the contaminants, one-inch strips of hot melt were extruded onto samples of the basestock. To control accurately the weight of the hot melt additions, each basestock sheet was weighed before and after the hot melt was applied. This gave us the exact weight of the hot melt applied to each sample sheet. Once the amount of hot melt needed was prepared, the sheets containing the adhesive were shredded with a paper shredder. This generated strips of hot melt 1/4-in. wide, similar to actual bead widths found in gluing operations. The sample was then disintegrated in a commercial Waring blender at high speeds for 13 minutes. This reduced the hot melt beads into pieces that approximated the size of contaminants typically seen in stock preparation operations in a recycle mill.

Cleaners

The trials focused on hot melts with a range of specific gravities from 0.840 to 1.300. Since this represents both light and heavy rejects, two types of cleaners were used.

For removal of light rejects, a Beloit Uniflow (through-flow) cleaner was used. A 4" Bird Escher Wyss Cyclene forward cleaner was used for heavy rejects.

Trial plan

For each trial, the pulped stock was placed in a 120-gal tank and diluted to a total of 80 gal (0.7% consistency) using hot water. For the first five trials, the resulting stock temperature reached 90°F. Subsequent trials were run at higher temperatures of 120°F after adjusting the temperature of the water heaters. The desired amount of hot melt contaminants was added and dispersed in the stock with an air-driven stirrer. Once the stock was well mixed, a feed sample was withdrawn from the tank. Stock from the tank was circulated through 4-in.-diameter hoses, a centrifugal pump, the cleaner, and—by way of accept and reject streams—back into the 120-gal tank. The stock was allowed to circulate in this manner until the correct conditions were obtained. In the case of the Beloit Uniflow cleaner, the desirable condition was to maintain a 2-gal/min reject rate. Inlet and accept pressures were adjusted until the desired reject flow was reached. For the Bird Escher Wyss forward cleaner, the desired condition was a feed flow of 40 gal/min and a 45-psi pressure drop. After reaching a steady-state condition, the accept and reject flows were separated and allowed to flow into separate tanks until the tank was about one half to three fourths empty. The trial was then ended and trial time noted. Information gathered during each run is listed in **Table I** for through-flow cleaner and **Table II** for the forward cleaner.

From the feed accept and reject samples, consistencies were determined. Handsheets for contamination counts were made using a British sheet mold. Handsheets were not made on reject samples due to the high concentrations of hot melt material in the majority of reject samples.

Tables III and IV list the results on stock analysis along with the removal rating for each hot melt.

Removal efficiency

Figures 1 and 2 exhibit the removal efficiency as a function of specific gravity for both types of cleaning. Note that, with through-flow cleaning, the efficiency of removal peaks at 0.980 specific gravity and appears to level out at that point. There also appears to be a slight reduction in efficiency as the contaminants in the feed are increased. This emphasizes the need for a recycler to do an adequate job of screening before the cleaner for best efficiency. This will also greatly reduce cleaner plugging. Similarly the removal efficiency with forward cleaners increases as the specific gravity increases to an efficiency of 90% at a specific gravity of 1.050. **Figure 3**, a composite of the previous two figures, identifies the critical range of 0.980 and 1.050 as the specific gravities that cannot be efficiently removed with

I. Data for through-flow cleaners

Trial no.	*Specific gravity*	*Addition by weight % on OD*	*Cleaner type*[a]	*Trial time, s*	*Stock temp., °F*	*Delta P*	*Accept flow, gal/min*	*Reject flow, gal/min*	*VRR*[b]	*MRR*[c]
2	1.010	1	TF	40	115	18.0	31.5	1.95	5.8	0.06
3	1.010	2	TF	135	90	19.5	26.2	2.30	8.1	1.00
5	0.995	1	TF	44	114	21.0	27.3	1.90	6.5	1.50
6	0.986	1	TF	48	115	20.0	31.2	2.30	6.0	1.00
7	0.980	1	TF	61	120	20.0	29.5	1.97	6.3	1.20
8	0.960	1	TF	51	121	22.0	31.8	1.76	5.1	1.10
9	0.960	1	TF	48	120	17.0	31.3	1.98	6.0	1.30
10	0.940	1	TF	53	119	20.0	31.0	1.98	6.0	0.90
11	0.940	2	TF	124	88	20.0	26.6	1.90	6.7	2.30
12	0.840	2	TF	122	88	20.0	26.1	1.09	6.7	1.40

[a]TF = Through-flow cleaner
[b]Volumetric reject rate =(reject flow gal/min/total flow gal/min) x 100
[c]Mass reject rate = (rejects tons/day/feed tons/day) x 100

II. Data for forward cleaners

Trial no.	*Specific gravity*	*Addition by weight % on OD*	*Cleaner type**	*Trial time, S*	*Stock temp., °F*	*Delta P*	*Accept flow, gal/min*	*Reject flow, gal/min*	*VRR*	*MRR*
1	1.300	2	F	65	90	45.0	36.0	1.4	3.7	16.00
4	1.010	2	F	80	90	45.0	38.3	1.3	3.3	17.20
13	1.030	1	F	35	119	45.0	36.0	2.6	6.7	28.00
14	1.050	1	F	31	119	45.0	36.6	2.7	7.3	33.00
15	1.100	1	F	33	119	45.0	34.5	2.5	6.7	31.00

*F = Forward cleaner

either type of cleaner.

The work described above demonstrated that, as the specific gravity of hot melt adhesives increased from 0.840 to 1.010, the efficiency of the through-flow cleaner dropped. Efficiency was determined by counting the area of the stickies compared to total weight of handsheets made from feed and accepts according to Eq. 1.

Subsequent work showed that above 0.980 specific gravity the efficiency drops off precipitously in the equipment we used to an efficiency of about 40%. This compared to over 90% below 0.980 specific gravity for hot melts. The critical region of 0.980 to 1.010 makes hot melts that fall into this group impossible to remove efficiently with a through-flow or reverse cleaner.

Similar experiments were done utilizing a forward centrifugal cleaner designed to separate and remove heavy contaminants from the recycled pulp stream. To determine the specific gravity at which the removal efficiency declines in forward cleaners, special hot melt adhesives had to be formulated with specific gravities of 1.029, 1.052, and 1.106, since commercially available hot melts were not available in this range. We also used commercially available hot melts with specific gravities of

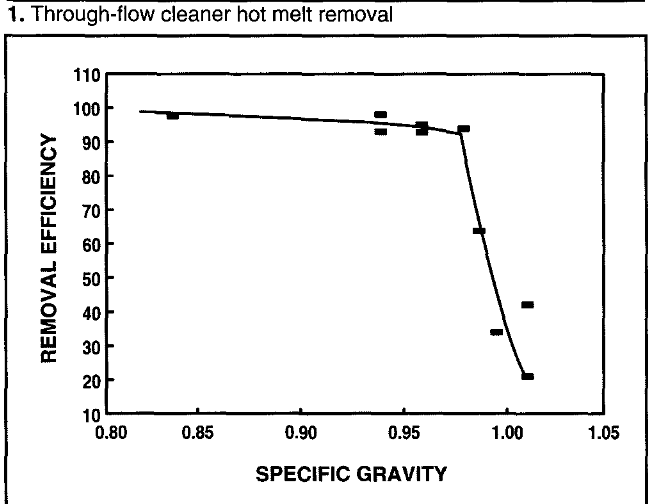
III. Analysis of through-flow cleaners

Trial no.	*Specific gravity*	*Feed consis., %*	*Accept consis., %*	*Reject consis., %*	*Feed flow, gal/min*	*Stickies feed, mm²/g*	*Stickies accepts, mm²/g*	*% efficiency*
2	1.010	0.73	0.72	0.08	33.5	181	104.8	42.0
3	1.010	0.68	0.75	0.09	28.5	476	377.0	20.8
5	0.995	0.77	0.81	0.18	29.2	175	115.0	34.3
6	0.986	0.75	0.71	0.12	37.5	266	97.0	63.2
7	0.980	0.76	0.72	0.13	31.5	99	6.5	93.0
8	0.960	0.76	0.69	0.14	34.7	100	6.3	94.0
9	0.960	0.74	0.70	0.14	33.2	291	22.0	92.0
10	0.940	0.74	0.77	0.12	33.0	149	3.6	98.0
11	0.940	0.73	0.72	0.25	28.5	396	30.0	92.4
12	0.840	0.66	0.74	0.14	28.0	127	3.0	97.6

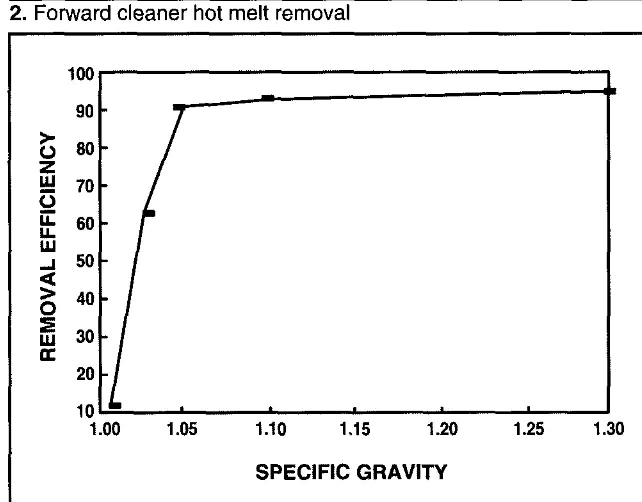
IV. Analysis of forward cleaners

Trial no.	*Specific gravity*	*Feed consis., %*	*Accept consis., %*	*Reject consis., %*	*Feed flow, gal/min*	*Stickies feed, mm²/g*	*Stickies accepts, mm²/g*	*% efficiency*
1	1.300	0.68	0.59	3.0	37.4	284	16.0	94.4
4	1.010	0.66	0.60	2.6	39.6	610	539.0	11.6
13	1.030	0.71	0.46	2.9	38.6	215	80.0	62.8
14	1.050	0.60	0.43	2.7	36.6	205	20.0	90.2
15	1.100	0.59	0.45	2.8	37.1	182	14.0	92.3

1. Through-flow cleaner hot melt removal



2. Forward cleaner hot melt removal



1.010 and 1.300. Hot melt adhesives normally tend to have specific gravities less than 1.0 so that the user is able to obtain more mileage for each pound of product. This set of trials demonstrated that the removal efficiency of forward centrifugal cleaners significantly improves as the hot melt specific gravity increases from 1.010 to 1.050 at which point there is a 90% removal efficiency.

Hot melt differences

This work shows that specific gravity is the key characteristic even with hot melts having different formulations. Two hot melts with the same specific gravity of 0.960, but having different base polymer, showed similar removal efficiencies.

On the high side, efficiency of hot melt removal with a forward cleaner removal is still lower at a specific gravity of 1.050 than removal efficiency with a through-flow cleaner at 0.980 specific gravity. Efficiency of removal with a forward cleaner improves as the specific gravity is raised to 1.30.

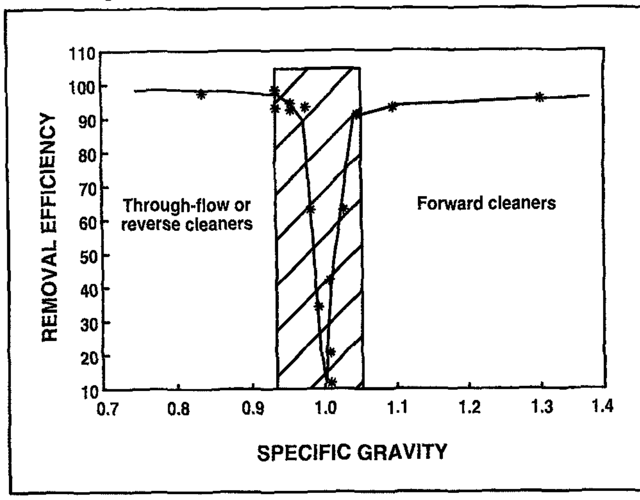
We limited our recommendations of heavier-than-water hot melt due to the lower mileage of hot melt for each pound of adhesives and the greater difficulty in removal. The preferred direction is toward the lower specific gravity adhesives because they provide better mileage for the user while being easier to remove for the recycler.

The recycler will then have to install through-flow or reverse cleaners. One supplier provided the specific gravities of their top ten selling hot melt adhesives. Of these, three were in the problematic range between 0.985 and 1.010. These adhesives were typical packaging grades and were based on ethylene vinyl acetate with wax and tackifier components. The synthetic and microcrystalline waxes commercially available for hot melt formulators range from 0.90 to 0.99 in their specific gravities. The hydrocarbon and rosin ester tackifiers used can range from 0.93 to 1.05 and are likely to be the component that most often will raise the specific gravity of the final hot melt adhesive formulation above the 0.985 level.

Both polyethylene and ethylene vinyl acetate based hot melts will undergo changes in their specific gravities as their temperatures are raised. These changes are a result of phase transitions in the crystallinity of the components of the hot melt. The increase in volume causes the specific gravity to decrease. Under mill conditions where pulping temperatures can range from 120-140°F, we would expect minimal changes in the specific gravity of the adhesives we tested. At these temperatures, only the wax components would reach their melting points.

All specific gravities of the hot melts used in our experiment and listed in Tables I–IV were measured by volumetric displacement methods in either water or alcohol at room temperatures.

3. Centrifugal cleaner hot melt removal



Conclusions and recommendations

Hot melt adhesives are more efficiently removed when their specific gravity falls outside a certain critical region. We have identified 0.980 as the upper limit for removal with through-flow cleaners and 1.050 as the lower limit for removal with forward cleaners. Specific gravity, rather than chemical composition, is the significant characteristic influencing removal efficiency in centrifugal cleaners based on the comparison of polyethylene and ethylene vinyl acetate based hot melt adhesives. We hope the fervor for using recycled paper and recyclable materials will expand so that our packaging technology can become truly integrated therein. This requires more communication and cooperation among various processors in the packaging cycle.

Our suggestion to adhesive manufacturers would be to reformulate their products to perform outside this problematic range. To promote efficiency in removal during recycling, converters should specify hot melt adhesives with specific gravities readily removable with centrifugal cleaning but consistent with providing satisfactory performance in their packaging and converting processes. For light hot melts, we recommend specific gravities below 0.980. While we recommend a specific cut-off point for heavy hot melts below a specific gravity of 1.050, users should avoid hot melts with specific gravities similar to water or higher. Paper mills contemplating the purchase of through-flow or reverse cleaners should require information concerning the removal efficiency of materials at various specific gravities. In addition, further studies should examine this relationship with respect to the following variables:

- Alternate cleaners
- Pulp consistency variations
- Pulp temperature changes
- Alternate pulps.

Control of the specific gravity of a hot melt adhesive contaminant is critical to efficient removal in centrifugal cleaners. Our work shows that adhesives with specific gravities ranging from 0.980 to 1.050 are very difficult to remove efficiently in centrifugal cleaners. This leaves fine screening and dispersion as the only normal means of cleaning. Many mills do not have this equipment, and purchasing it would be very expensive. In addition, when adhesives are outside the critical range, screening and disperging are not as effective as centrifugal cleaning for removing the stickies. TJ

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