A PILOT PLANT STUDY OF THE RECYCLABILITY OF PRESSURE SENSITIVE ADHESIVES (PSA)

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ABSTRACT

This paper discusses the operation and results obtained from a pilot plant study of the recycleability of post consumer PSA postage stamp material. The trial work was carried out in May of 1997 at the Beloit Corp. Pulping Group Pilot Plant in Pittsfield MA.. in cooperation with the U.S. Postal Service. and the U.S.D.A. Forest Products Lab in Madison WI.. This work is a part of a much larger USPS development program currently under way with the main objective being "to develop postage stamps that do not adversely affect the environment". The goal of the project is to develop a PSA material which can be successfully recycled in the typical mixed office waste (MOW) deinking system producing a pulp for inclusion in printing and writing grades. This trial looks at a PSA currently being used in the manufacture of the postage stamp laminate material and its removal in a pilot plant system configured in such a way so as to mimic the first loop in a typical MOW deinking system.

INTRODUCTION

Beloit was contacted by the USDA Forest Products Laboratory, Madison, WI in March of 1997, and asked to undertake a pilot plant study of the recyclability of the postage stamp laminate material. This study was a part of the U.S. Postal Service's efforts in developing environmentally benign pressure sensitive adhesives for use in the postage stamp program. The trial was conducted in the Beloit Pulping Group Research and Development Center in Pittsfield, MA on May 9, 1997. The trial used primarily commercial sized equipment installed the pilot plant recycled fiber system. The trials were conducted following a system design, and the testing protocol developed and provided by the Forest Products Laboratory. The objective of this trial was to study the removal of Pressure Sensitive Adhesive (PSA) in the various contaminant removal operations which are currently found in today's typical Mixed Office Waste (MOW) deinking systems.

EQUIPMENT & PROCEDURE

The trial plan and procedure was designed to follow as closely as possibie the testing protocol provided by the USDA Fores; Products Lab. The material used for the trial was a blend of 95%, clean, 20# basis weight, Xerographic copy paper. and 5% unprinted standard stamp laminate adhered to a portion of the copy paper. The adhesive provided as a component of the stamp laminate was a water based acrylic. This trial was intended to simulate a post consumer waste stream. and as such contained no release paper. The system design was provided as part of that protocol. and consisted of; high consistency pulping, coarse and fine screening (0.30 mm and 0.15 mm slots respectively). forward cleaning, through flow cleaning, flotation, washing, and dispersion as outlined in the following block diagram. This trial was run in batch operation mode rather than on a continuous basis in order to minimize the quantiity of material required to conduct the trials.

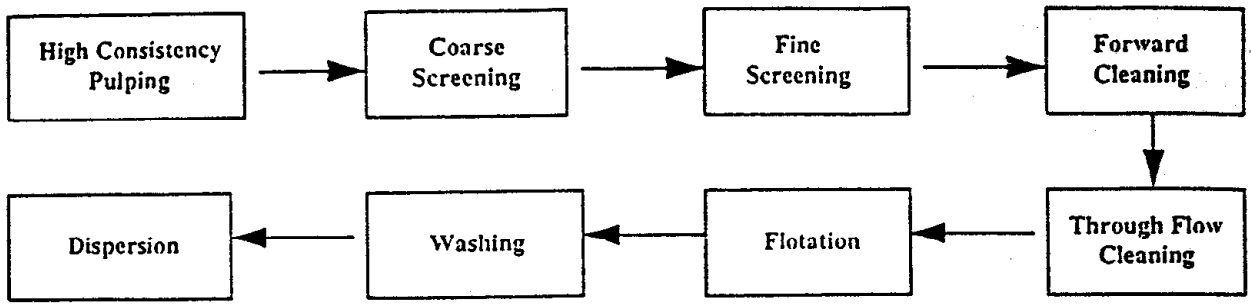

Figure 1. The system block diagram.

A 360 kg pulper batch was prepared in the laboratory Helidyne pulper such that it contained the required proportions of stamp material & clean copy paper. Sufficient water was placed in the pulper to result in a 15% pulp consistency (after pulping). pH adjusted to 10, and heated to 40° C with the addition of direct steam. The pulper was started and the copy paper added to start the breakup of this material prior to adding the stamp material. This process took approximately 4 minutes with the pulper impeller running at 200 RPM. At that time the impeller speed was increased to 300 RPM (the normal operating speed) the stamp material was added and the pulping timer started. pulping time from that point was 20 minutes.

Upon completion of the required pulping time, the pulp was diluted (in the pulper) to 6.0% consistency and pumped into the screen feed chest for further dilution to screening consistency. Both of the dilution steps used warm dilution water so as to maintain the operating temperature at 40° C. The coarse screening operation was carried out at 2.7% consistency using a Multi-Rotor (MR-18) screen equipped with a 0.30 mm slotted contour screen basket and an "S"-rotor. The screen accepts were discharged into a stock chest for further processing, and the screen rejects were taken into the screen rejects tank. and then into the pilot plant rejects handling system for disposal. The screen was thoroughly flushed with clean water and converted to the fine screen configuration by installing a 0.15 mm slotted RSC screen basket and foil rotor. The stock was transferred back into the screen feed tank and diluted, again with warm fresh water, to the targeted 1.18 consistency for the fine screening operation. Feed. accepts and rejects samples were taken from both the coarse and fine screening operations for testing and evaluation.

Forward (heavies) cleaning was the next operation to take place, and that used the 3" Posiflow Ultra. This cleaner operates with a 4.4 kPa pressure drop and atmospheric rejects discharge. The fine screen accepts was transferred into the cleaner feed tank and diluted with warm, fresh water to the targeted 0.8% feed consistency for the forward cleaners. The cleaner accepts flow was taken into an accepts tank, and the rejects discharged to the waste treatment system. Feed, accepts and rejects were collected for analysis during the cleaner operation. The "heavies" cleaning operation was followed by two passes of Uniflow cleaning for removal of the lightweight contaminants. The forward cleaner accepts were transferred from the cleaner accepts chest back into the cleaner feed chest for processing in the through flow cleaners. The cleaner accepts were taken to a chest. rejects discharged to the waste system and samples collected for analysis. The same procedure was followed for the second pass of lights cleaning. No additional dilution took place prior to either of the two passes of through flow cleaning.

Flotation, using the Pressurized Deinking Module (PDM-75), followed the cleaning operations in the trial plan. This is a pressurized flotation cell which utilizes dispersed and dissolved air in the pulp to float the targeted contaminants to the surface of the pulp, and separate them from the cleaned pulp. The cell consists of an inlet zone where compressed air is added to the pulp stream, followed by a static mixing zone where the contaminant particles are made to contact the air bubbles. The pulp discharges from the mixing zone into the flotation chamber where the air bubbles are allowed to carry the contaminant particles to the surface of the pulp. The rejects pass over a weir, and are conveyed under pressure to a liquid/gas cyclone which breaks the foam and extracts the air. This allows the contaminant laden rejects stream to be pumped to the system rejects handling system. The cleaned pulp passes under the weir, and is conveyed under pressure to the next unit operation in the system. The stock was prepared for flotation by checking pH to determine if it was in an acceptable range and followed by the addition of the flotation chemistry (used to aid the attraction and adhesion of the contaminants to the air bubbles). The pH was determined to

be 8.6 so no adjustment was made and 0.1% flotation aid added prior to the flotation cell startup. The flotation cell was Fed at a flow rate of 265 LPM at 3.0 kPa inlet pressure, with a reject flow of approximately 10 LPM.

The next unit operation to take place was pulp washing using the Beloit DW-18, Dynamic Washer. This is a pressurized mechanical washer utilizing a drum type rotor rotating inside a cylindrical filter media having 0.008" diameter electron beam drilled holes. The Feed stock is conveyed under pressure into the annular area between the rotor and filter media. Water and small contaminants are allowed to pass through the filter media, while the fiber is retained on the surface of the media and through the device to the stock discharge port. The rotor is rotated at such a speed so as to keep the pulp fluidized and not Form a fiber mat on the surface of the filter media, The thickening ratio (water extraction) and production rate are controlled by means of flow control valves on both the effluent and fiber discharge streams. The flotation cell accepts was discharged directly into the washer Feed chest. and again no Further dilution took place prior to this operation. The washer cake discharged From the washer at 3.4 % consistency and was thickened to 44 % consistency using a centrifuge in preparation For a bench scale dispersion operation and shipment to the Forest products Lab. The centrifuge cake was broken up using the lab cake breaker For the dispersion operation, The final operation to take place was dispersion and it used the 12" single disk refiner equipped with tine bar pattern dispersion plates.

All sample collection and testing. except stickies analysis, was carried out by Beloit Technical Personnel according to Tappi Standard Procedures. Stickies analysis was performed using the Optomax Speck Check. 600 DPI scanner based system Following a procedure developed and provided by the USDA Forest Products Lab in Madison. WI.

DISCUSSION

The stamp stock was affixed to a portion of the copy paper prior to being introduced info the pulping operation. and as such simulates a post consumer waste stream (no release paper). The 5% addition rate of the stamp material is clearly higher than that which would be normally found in the typical Mixed Office Wastepaper used as a raw material For the production of recycled pulp to be used in the manufacture of copy paper. This addition rate does however, supply a high enough population of stickies in the pulper sample to allow a reasonable measurement of contaminant reduction as the pulp is processed through the system during the trial.

The pulping process resulted in complete defibering (99.9%) of the copy paper Furnish after the 20 minute pulping time. The Tappi dirt count as measured by the scanner, using the Forest Products Lab's protocol was 3594 PPM and 1.0% by weight as measured by the 0.006" Valley Flat Screen. A visual examination of the pulper handsheets and particle size distribution clearly shows that this adhesive breaks up in the pulper into generally larger sized particles (greater than 0.30 sq. mm). This is an advantage in the contaminant removal processes where the larger contaminants are easily removed in the slotted screens at relatively high removal efficiency. This is true even with deformable materials such as PSA provided the system temperature is kept relatively low (below approximately 120° F). Dirt reduction For the combined screening operations was calculated to be 95.5% based on the scanner measurements. There is a very clear concentration of large stickies in the coarse screen rejects sample and somewhat smaller stickies in the fine screen rejects. There was no indication of the PSA material adhering to the screen basket surfaces or imbedded in the slots of either the 0.30 mm or 0.15 mm slotted baskets at the completion of either screening operation.

The testing results of the cleaner samples from both the Forward and through flow cleaners show some scatter and at best modest removal of the PSA material. At this point in the system where the accept dirt counts are relatively low. below 100 PPM. scatter in the data often makes evaluation of unit operations difficult. This is especially true when combined with relatively modest removal rates such as those seen in the cleaners. In such cases it is often useful to examine the debris concentration in the rejects samples. A visual examination of the rejects handsheet samples from both the Forward and through flow cleaners shows very little if any concentration of the PSA material. particularly with the light weight cleaners, which supports the measurements made on the accepts samples. This is supported in the case of the forward cleaning operation by the scanner measurements which show essentially the same counts in the rejects sheets as For the accepts sample. The through flow cleaner rejects samples could not be scanned due to the very low fiber content of that sample (0.13% consistency) and that fiber being all fines. making it impossible to

Form a handsheet using the Tappi handsheet mold. The through flow cleaner rejects samples are drained on filter paper in a Buchner Funnel in order to give a visual indicator of the materials Found in the rejects.

The floatation operation. while nor providing an increase in removal based on the Feed (Through Flow Cleaner 2 Accepts sample) to accepts samples. does show concentration in the rejects stream. A visual examination of the floatation cell rejects handsheets confirms that there was a significant concentration of the PSA material particularly the smaller sized particles. This is supported by the scanner results which show the flotation cell accepts at 78 PPM compared to the rejects sample at 826 PPM. This conclusion is also supported by a Denver Cell Flotation test undertaken on the second pass through flow cleaner accepts sample. This test was carried out to determine if more than on pass of floation would improve the removal efficiency of that process. That bench scale flotation operation yielded a Tappi dirt count of 13 PPM, compared to 78 PPM For the single pass of flotation in the pilot plant. This then indicates that the additional passes of flotation which would be generally installed in the typical MOW deinking system should provide additional removal of the PSA material over and above that which was obtained with the one pass of flotation used For the trial.

The Dynamic washer also shows some removal of the smaller sized PSA material which brings the over-all system reduction to 99.5% as measured by both the scanner and the Valley Flat Screen methods. That system reduction brings the Tappi dirt count of the Washer cake down to 18 PPM which is quite reasonable For the "simple one loop system" used For these trials. The Following table provides the trial results and compares those results with samples taken from equivalent locations within an operating commercial MOW system:

Table I. Stickie counts and cumulative system reductions compared to a commercial MOW deinking system.

PSA (Stickie) Reduction				
	Pilot Plant Trial		Commercial MOW System	
	Dirt Count	Reduction	Dirt Count	Reduction
Pulper	3594 PPM	------	978 PPM	0.0 %
Coarse Screen	3613 PPM	0.0 %	-----	-----
Fine Screen	161 PPM	95.5 %	-----	-----
Forward Cleaning	85 PPM	97.6 %	-----	-----
Through Flow Clr. 1	52 PPM	98.6 %	-----	-----
Through Flow Clr. 2	54 PPM	98.5 %	-----	-----
Flotation	78 PPM	97.8 %	-----	-----
Washing	18 PPM	99.5 %	54.9 PPM	94.4 %
Dispersion	48 PPM	98.7 %	8.0 PPM	99.2 %

The MOW deinking system to which the pilot plant results are compared was configured differently although much the same equipment is installed between the pulper and SDR inlet (washer outlet) is the same. Two points are clear From this data: the stickie count in the pilot plant pulper sample is 3.7 times that measured in the commercial system, and the reduction rates are very similar.

The addition of dispersion operations to deinking systems has been traditionally done to break down the remaining larger ink particle sizes and release any ink which may still be adhering to the fiber. This operation generally takes place at the end of the first loop in the system. The intent is of course to modify the remaining inks in such a way as to allow heir removal in additional passes of flotation, cleaning, and washing, or reduce the size such that they are no longer visible. There are two schools of thought with regard to the effect of dispersion on stickie particles like the PSA material being tested in these trials. One theory states that dispersion can act on the stickies in much the same way as it does on the ink particles; that is to modify their size, shape and detach them From the fiber so that they cd be removed in subsequent operations. This is often done using the "gentile" dispersion action of kneaders. Unlike the ink particles, this operation is intended to allow the stickies to contact each other, agglomerate and grow in size thereby allowing easier removal in fine screening or other subsequent contaminant removal operations. The other theory, which more often uses the higher intensity disk type dispersers such as the one used For this trial, promotes reduction in particle size such that they become invisible and are carried with the fiber through the papermaking

process. In this way the stickies end up in the sheet. but are of such a small size that they are not visible, so are not considered to be a sheet defect.

The placement of a dispersion process which is designed to reduce the particle size of stickies at the end of the deinking system *can* provide misleading and undesirable results: The stickle count at the end of the recycling system can be measured and found to be at an acceptable level. but the dispersed materials have not actually been removed from the pulp. When the deinked pulp is taken into the papermaking process its pH is often dropped below pH 7.0. This may result in the agglomeration of any remaining contaminants. including stickies, both in the pulp stream as well as in the white water system. Those agglomerated materials can cause defects in the final product and build up on the wires and felts of the papermachine causing operational problems and down time. It is therefore advantageous to remove as much of these materials as possible in the contaminant removal processes so as to avoid the problems associated with operation of the papermachine and contaminating the white water system. This then maximizes production time while minimizing operational costs for replacement of plugged felts and wires.

The trial results from the SDR tend to indicate that some agglomeration has taken place. This is based on the pulp discharge from the washer (SDR inlet) having an 18 PPM dirt count and the SDR outlet was measured at 48 PPM. While this may suggest that some contaminants smaller than the 0.04 sq. mm size have agglomerated and caused the increase in the larger sized particles, the count of particles below 0.04 sq. mm increased as well. The dirt count of particles sized between 0.002 and 0.04 sq. mm for the washer discharge was 14 PPM compared to 29 PPM for the same particle size range found in the SDR outlet sample. This is the particle size range which would be expected to be increased in the disk type dispersion operation used for these trials. This then suggests that the discharge pulp from the washer was re-contaminated either in the thickening process or in dispersion itself. Thus the dispersion results are inconclusive.

CONCLUSIONS

The adhesive used for these trials is one being used currently in postage stamp production and as such provides the baseline against which additional adhesives can be compared. These pilot plant trials provide data with regard to the expected removal efficiencies for the typical “state of the art” recycling equipment and systems against which other adhesives can be compared as part of the US Postal Services developmental program.

The adhesive provided for the trials breaks down in the pulping process into primarily larger sized particles, 0.3 sq. mm and above. This is an advantage in the recycling process since those materials which show the greatest difference in size, shape, or specific gravity to fiber are the materials which are the easiest to remove, and result in the highest removal efficiency. In this case, the combination of the coarse and fine slotted screens (0.012” and 0.006” slots) are very effective at removing particles in this size range from the pulp. Removal of all visible size particles (0.040 sq. mm & above) was over 95% at the fine screen accepts.

Over-all PSA removal across the entire system was 99.5% as measured by the scanner, with the flotation and washing operations providing the additional removal (over the screens). Denver Cell flotation of the through flow cleaner accepts indicates that the additional passes of flotation which would normally be installed in the typical MOW deinking system would provide additional removal of the PSA materials over the trial results. It is possible to result in final dirt counts below 10 PPM with the additional passes of flotation. compared to the 18 PPM achieved by the trial. The cleaners, both lights and heavies were not effective at removing this PSA material due to its specific gravity and particle size remaining in the pulp after screening.

This PSA material is removable at over 99% efficiency using the conventional unit operations found in the state of the art mixed office waste deinking system. The inclusion of materials containing postage stamps using the adhesive tested for this trial should not cause significant additional problems to the paper recycler due to the PSA used on the stamps.