STICKIES REMOVAL IN A DEINKING LINE OF A NEWSPRINT MILL: EFFICIENCY OF THE DIFFERENT PROCESS STAGES

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The study evaluates stickies removal efficiency of the different process stages in a deinking line of a newsprint paper mill, using 100% recovered paper as raw material. Two different situations have been considered, namely, a normal one, with a low level of stickies at the beginning of the line, and a critical situation with a high level of stickies. Removal efficiencies have been compared with data available in the literature. Although results show a high efficiency of the process for contaminants removal in both cases (80-90%), residual stickies levels at the end of the line are very different (a double initial stickies content causes four times higher stickies content at the end of the line). The first loop is the most critical step, removing 72% of the inlet stickies to the line. The most efficient units are preflotation and the second thickening stage (disc filter 2).

Keywords: stickies, recovered paper, deinking line, newsprint, solvent extraction, dichloromethane

INTRODUCTION

The recovery and utilization of recovered paper have increased over the past decades all over the world, and this trend will continue. In the European Union, a 56% recycling rate was achieved in 2005, according to the voluntary target of the industry, adopted in 2000 under the background of the European Declaration on Paper Recovery,[1] which means the use of 47.5 million tons of recovered paper as raw material for the European paper industry. At this moment, a new target is under discussion to further boost paper recycling, so that more than 57 million tons of recovered paper will be used in 2010. To reach the new target, several conditions are required: increase of the collection rate; improvements in the quality of the recovered paper delivered to the recycling mill and improvements in contaminants removal efficiency in the recycling plant.

The quality of recovered paper constitutes an important aspect for the production of high quality recycled fibers and for increasing the recycling rate. However, the quality of the recovered paper decreases at high recycling rates.[2,3] Among the contaminants present in recovered paper, stickies are probably the most problematic ones for recycled paper manufacturing, if considering the adhesive contaminants that agglomerate from hot-melt glues, pressure-sensitive adhesives, coating binders, thermoplastic resins, inks and waxes that are typically found in secondary fiber furnishes.[4,5]

Although no precise definition of the term “stickies” is available, the term is commonly used to describe various materials and the numerous problems to be faced in recycling and papermaking processes. These problems affect both the process efficiency (breaks, formation of deposits on various equipments of the paper machine, reduction of the drying section efficiency due to felts clogging, etc.), and the quality of the final product (presence of spots, holes and other defects).[6,7]

Several classifications of stickies have been proposed in the literature, based on different characteristics, but the most common one refers to size.[6,8] Thus, macrostickies are considered those retained on 0.10 or 0.15 mm slotted screens, while microstickies are those able to pass through. The reason of such a classification is that, generally, macrostickies are removed by the screens and cleaners of the recycling process, while microstickies are usually so small they can not be removed from the pulp by screens and cleaners and eventually agglomerate and form deposits on paper machine wires and felts. Microstickies can be further classified as suspended, dispersed, colloidal and dissolved stickies.[9] Suspended stickies may cause deposition on paper machine clothings, while dispersed, colloidal and dissolved stickies may precipitate out on dryer's cylinders, while colloidal and soluble materials could potentially form secondary stickies. Recent studies[10,11] have demonstrated that microstickies form the predominant stickies category found in recycled pulp (as 70 to 80% of the current total stickies content comes from microstickies). The consequence of this finding is very important in term of stickies control strategy. Indeed, solutions to improve microstickies removal (or control) have to be further developed. Thus, the deinking stages and the process water treatments require urgent improvement, for optimizing microstickies removal, thus constituting a step forward in dealing with stickies.[7]

The key to the utilization of recovered paper is contaminants' removal as early as possible during the recycling process, *i.e.* stickies should be efficiently removed during stock preparation of recycled pulp to ensure paper machine runnability, trouble-free converting and high-quality products.[12] Stickies have an important influence on the total production cost and on the competitiveness of the mill (the costs estimated to stickies related problems are around 20 €/ton[8]), being an additional burden on the paper industry which has an especially narrow profit margin to begin with.[13] Future scenarios on recycling paper industry, in which stickies levels are going to increase still further, while quality is going down and the recovered paper utilisation rates are going up (for example, the proportion of stickies in deinked pulp increased more than double between 1996-2000 in a survey performed mainly within German paper and board industry[14]), will suppose a challenge in the years ahead for the recycling industry, and a more complex recovered paper processing will be necessary.[14,15]

Stickies quantification is essential during recycling to control the problems they cause. It is important to control the quality of the raw materials, to design recyclable products, to improve the control strategies, to assess the behaviour of contaminants under different conditions, to understand the interaction of water streams with contaminants with contaminants or to determine the efficiency of control programs and for the optimization of the wet end chemistry.[2]

Several methods for stickies quantification – all evidencing both advantages and drawbacks – have been proposed by different authors. In most cases, the main limitations of these methods are their reproducibility and the good performance, yet restricted to very specific types of stickies. Macrostickies are quite well known species, since these particles are relatively easy to isolate and, consequently, measureable.[7,16] Indeed, numerous methods, permitting to quantify the macrostickies content in a recycled pulp, have been developed. The most common methods for macrostickies measurement involve a lab screening step (100-150 μm slotted screen), permitting to isolate the stickies from the recycled pulp. On the contrary, the situation is different for micro and colloidal stickies, for which lack of accurate monitoring tools is recorded.[7,16]

Several studies have tried to compare the different quantification methods, yet the establishment of a universal method is still a distant objective.[9,17,18]

Most of the methods proposed for micro and colloidal stickies involve deposition tests, aiming at assessing the deposition of micro or colloidal stickies on particular surface and under very specific conditions.

Such deposition tests do not measure microstickies' concentration, but only provide an estimation of the stickies quantity which may be deposited under the specific conditions of the test.[11-19] Recently, new methodologies have been developed by various research teams to directly measure the concentration of micro and colloidal stickies in pulp samples based on improved solvent extraction[10,11] or on total organic carbon (TOC) of the filtrates obtained by filtration and ultra-filtration.[16,20]

It has been demonstrated that the paper machine deposits contain numerous compounds which are extracted by dichloromethane (around 30-50% of the components).[21] Other advantage of this method is the possibility to determine the nature of the compounds involved in the formation of stickies by means of FTIR analysis of the extracts. This technique is very useful to detect recalcitrant or refractory stickies and their evolution along the process.[22-24]

The paper evaluates the contaminants removal efficiency in the deinking line of a recycling plant, using 100% recycled paper as a raw material, under both normal and critical conditions of stickies levels. Evaluation of stickies has been done by solvent extraction with dichloromethane, to facilitate a comparison with available data on total stickies levels and with the process efficiency from other deinking lines.[10-11]

EXPERIMENTAL

Pulp samples have been obtained from a deinking line of Holmen Paper Madrid. The studied line, installed in 1998, produces 400 tons per day of DIP pulp from a mixture of recovered paper with an average composition of 6:3:1 old newsprint (ONP), old magazines (OMG) and office paper (OP), respectively. Figure 1 shows a simplified schematic arrangement of the deinking process and of the selected sample points, nine of which have been selected to carry out stickies mill evaluation. Samples were taken starting from the beginning of the line and considering the delay times between each stage.

To control pulp quality, the mill measures every day the macrostickies level at the end of the deinking line. Based on these data, samples of the first survey were taken over when unfavourable conditions were present at the line, according to a high content of macrostickies (around 300 mm^2/kg). For the sake of comparison with the normal situation, the second survey was carried out when regular conditions were present at the line, according to a low level of macrostickies at the end of the line (around 110 mm^2/kg).

The macrostickies were measured by the INGEDE Method 4, based on a laboratory screening procedure according to which, after screening, the reject is prepared in such a way that an image analysis of the adhesive impurities may be performed. Separation of macrostickies from the recycled pulp suspension was performed with a Sommerville tester (TAPPI UM 242) equipped with a 150 µm slotted screen. The results of image analysis are expressed in mm^2 per kg of dried pulp screened.

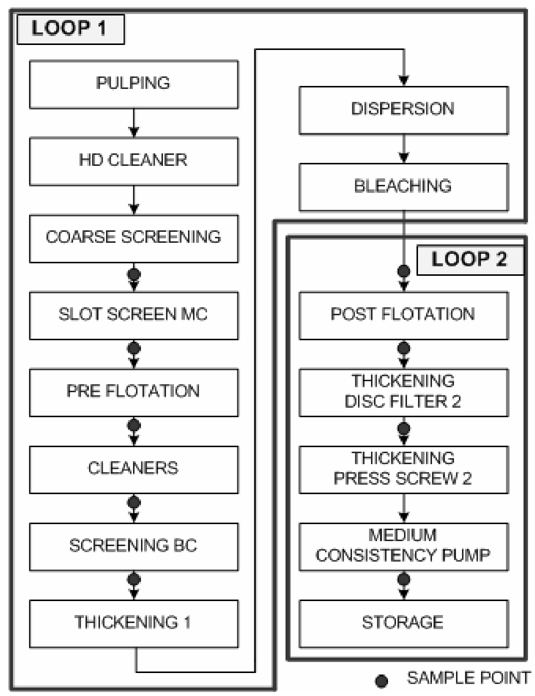

Figure 1: Simplified diagram of the deinking line and of the sample points

The total content of stickies in the pulp samples was measured by solvent extraction with dichloromethane. After sampling, the pulp samples were dried at 105 ºC without any pre-treatment. Extraction of 5-10 g of dried pulp was performed in a Soxhlet apparatus using 150 mL dichloromethane, for 5 hours. After extraction, the solvent was recovered and evaporated using a rotary evaporator, in a pre-weighted vessel. The residue obtained after solvent evaporation was entirely oven-dried at 105 ºC and finally weighted in an analytical balance for gravimetric determination of extractives content. All measurements were carried out in duplicate.

Average results on the extractives content (expressed in g/100 g dry pulp or %) and the standard deviation obtained from the replicates were calculated for each sample.

RESULTS AND DISCUSSION

Figure 2 shows the extractives content along the deinking line. In all measurements, the average relative error was always below 10% (9.9% in the 1st survey and 7.2% in the 2nd survey, respectively).

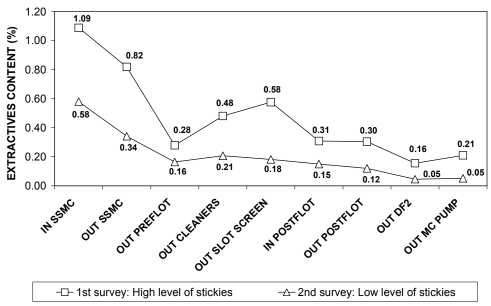

Figure 2: Extractives content along the deinking line. Results of the 1st and 2nd survey

Stickies content at the first point of the line is clearly different from one survey to another. The extractives content in the 1st survey is nearly double than in the 2nd survey (1.11% *versus* 0.58%). The efficiency of the whole stickies removal process is of 81% in the first case and of 92%, respectively, in the second case, while the residual stickies content at the end of the line is 4 times higher in the first survey (0.21%) compared to the second one (0.05%).

Removal of dichloromethane extractives is higher than in other published cases, including the deinking lines producing newsprint paper in which the global removal efficiency was around 70%, although it is equally important to notice that the first point in these surveys is the pulper outlet and the initial content of extractible materials is higher: 1.26%[10] and 1.33%.[11] If considering the first common sample point of these studies and of the here presented study, which is the inlet of preflotation, the efficiency of several deinking lines in removing stickies can be correctly estimated, although it does not include the stages prior to preflotation (coarse screening and slot screening of medium consistency, especially). From this point, the removal efficiency for the three studies is as follows: 74.4 and 84.7% in the first and second survey of this study, respectively, 71.5% in ref. 10 and 69.3% in ref. 11.

Modern recycling process can remove up to 95-97% of macrostickies, although some studies indicate that elaborate recycling processes can achieve more than 99% removal of macrostickies.[25] In this study, the total stickies content removal varied between 81 and 92%, yet the first point in these surveys is not the outlet pulper but the inlet to slot screen of medium consistency (high density cleaners and coarse screening were not evaluated in this study), once the very variable stickies content depends on the quality of the raw material. In general terms, it could be estimated that the hole screen may remove about 40-50% macrostickies; as to the initial size distribution of stickies, it considerably depends on pulping, stickies load and type, and, above all, on stickies' size distribution, although an overall hole pre-screening efficiency of 45% or of even 50% can be regarded as very good.[26] If assuming a 45% of efficiency of macrostickies removal in the hole screen, it may be viewed as similar to that of the total content of stickies removal; the initial level of stickies at the beginning of the line in the 1st survey is of 1.98%, and the final level is of 0.21% (89.4% removal efficiency) while, in the 2nd survey, the initial level of stickies is of 1.03% and the final level of 0.05% (95.2%).

Figure 3 shows the efficiency of stickies removal, attained in different studies, expressed as the stickies content of the inlet of preflotation *versus* the residual stickies content at the end of the line. A clear linear relationship is observed between the extractives content at the end of the line and the initial stickies content at the beginning of the line (in this case, beginning of the line is represented by the first common sample point in the different studies: the inlet of the preflotation unit), which indicates that the removal efficiency of stickies is very similar in the three deinking lines studied, and also that the stickies content at the beginning of the line will determine the residual stickies level at the end of the line.

Table 1 summarizes the efficiency of the different process stages in the removal of extractives, including the accumulated removal efficiency along the line for both surveys.

In both surveys, the more efficient units in removing stickies are the preflotation and the disc filter 2 (thickening step 2) as, in these stages, more than 50% of the inlet content of stickies was removed.

A slot screen of medium consistency and the *thickening 1 - dispersion - bleaching* sequence also reduced the extractives content of the pulp, although to a lower extent. There are two steps, the cleaners and the *press screw 2 - medium consistency pump* sequence that produced an increase in the total extractives content of the pulp.

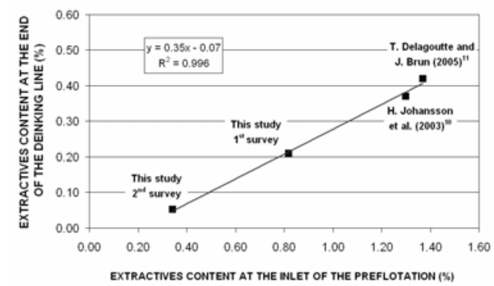

Figure 3: Extractives content at the end of the line *versus* extractives content at the inlet of preflotation. Comparison between published studies[10,11] and the present study

Table 1
Efficiency of stickies removal in each process stage and the removal accumulated along the deinking line

	Stages	Removal in each process stage (%)		Accumulated removal along the line (%)	
		1st survey	2nd survey	1st survey	2nd survey
LOOP 1	Slot Screen MC	24.7	42.6	24.7	42.6
	Preflotation	65.9	52.8	74.4	72.9
	Cleaners	-72.4	-40.9	55.8	61.8
	Fine screening BC	-19.8	21.2	47.1	69.9
LOOP 2	Thickening 1, dispersion and bleaching	46.5	7.6	71.7	72.2
	Postflotation	1.3	28.5	72.1	80.1
	Disc filter 2	48.8	61.1	85.7	92.3
	Press screw 2/ MC pump	-35.0	-11.4	80.7	91.4

Depending on the survey considered, the fine screening stage either reduced or increased the level of the inlet stickies.

The first loop is the key to a high stickies removal. In both surveys, a 72% reduction of stickies is achieved with respect to the first point of the sampled line. The second loop produces a further removal of either 9% (in the 1st survey) or 19% (in the 2nd survey). In a similar manner, the efficiency of the process stages is independent on the inlet content of stickies, yet the residual stickies content at the end of the line is very different (Fig. 3). A detailed analysis of each stage permits the following observations:

Stage 1. Slot screen of medium consistency with 0.25 mm slots. This unit removed, on the average, 34% of the stickies (25% in the 1st survey and 43% in the 2nd one, respectively), which agrees with the value attained in other studies[26] in which medium consistency slotted screens achieved a macrostickies reduction between 25-38% (*i.e.*, an average value of 31%).

Screens and cleaners are the most efficient units in macrostickies removal.[27,28]

Johansson *et al.*,[10] who carried out a thorough analysis of a 3-stage forward flow slotted screening systems, attained a 70% macrostickies removal, along with a 25%

increase in microstickies. The slotted screening systems remove macrostickies very effectively, yet the amount of microstickies is often higher after screening than before. This effect, which is the result of fibers thickening during screening, is further enhanced by the dilution of rejects, at each stage, with back water. The overall effect is a wash out of fines and microstickies from the rejects. In this stage of the process, the ratio of macrostickies in the total content of stickies is higher. Consequently, a global reduction of the total content of stickies is observed.

Stage 2. Preflotation with 6 primary and 2 secondary cells appears as the most efficient unit in removing the total content of stickies, with an average value of 59%, which is higher than the removal efficiency values recorded in literature, of 48.5%[10] and 30.7%,[11] respectively. Preflotation is considered a key process stage for stickies removal; by applying an improved flotation deinking technology, most of the residual stickies can be removed and efficiency can be increased up to 70%.[7] The main advantage of flotation (compared mainly to screening) is its potential to remove small stickies (microstickies) from the pulp suspension. Indeed, it is reported in various papers that small-size stickies, which are not affected by screening, show the best removal efficiency values during flotation.[25]

A detailed study on flotation[10] showed that the microstickies content, expressed as dichloromethane extractives content, decreased from 1.20% to 0.26% (78% removal). The reduction was of 96% for particle sizes of 20-76 μm, which coincides with the theoretical optimum range for flotation. In another study on the same deinking line in which is focused this paper, it was observed that the removal efficiency for macrostickies was very low, compared to that of the total stickies content (once the removal is focused on microstickies); in this case, preflotation removed 17.6% and 42.7% of the macrostickies.

Stage 3. Forward cleaners. In this stage, the total content of stickies is not removed, increasing up to average values of 57% (72% in the 1st survey and 41% in the 2nd one). This higher content of extractible material can be caused by the dilution waters added from the clear filtrate tank of loop 1, although this volume is not very large. Other studies[27,28] showed that the screen and the cleaners were the most efficient units in the removal of macrostickies. Indeed, an optimized four-stage cleaner plant can reduce macrostickies up to 80%,[29] although no reduction has been observed in this case in the extractible material. The macrostickies content is probably low as compared to microstickies content.

Stage 4. Fine slot screening (0.15 mm) increased stickies content in the 1st survey and decreased it in the 2nd one, practically to the same extent, *i.e.* around 20%. Consequently, fine slot screening is not very relevant in removing the extractives content of pulp. According to a survey[28] in which in which the macrostickies and extractives content were determined in the same deinking line, fine slot screening was the most efficient unit in removing macrostickies (low consistency, fine slotted screens can remove macrostickies within 70-95% range[23]) although only a small influence in the extractives content was observed Other studies[26] also evidenced, in a four-stage 0.15 mm slotted low consistency fine screening with centripetal type machine with the rotor on the inlet side, a very high reduction of macrostickies, up to 85-90%.

Stage 5. Sequence of *thickening 1 – dispersion – bleaching*. This sequence produced a 27% removal of the total stickies content. According to published data,[10] the thickening step of a first loop can remove around 19.7% of the extractives content. Consequently, dispersion and bleaching do not have considerable effects on stickies content, or their effects are contrary. After fine screening, the levels of macrostickies are very low compared to the values recorded before the process stages.[28] Consequently, microstickies represent the major source of extractible materials in the pulp, macrostickies and dissolved and colloidal stickies representing only a minor amount of the extractives material.

Stage 6. Postflotation (1 secondary and 4 primary cells) removed 16% of the total stickies content. Literature data[10] advance a very similar value of removal efficiency

(15.4%). Other studies[11] did not measure the removal between the inlet and the outlet of the postflotation, although recording a 23.2% increase of the extractives content between the outlet of the disperser and that of postflotation. This can be explained if assuming that the sample was taken over after the disperser, but before the dilution step necessary for preflotation. In this case, the necessary dilution is very high, once the disperser works at a 30% consistency, and the consistency in postflotation is around 1%. Consequently, the dilution between the outlet of the disperser and the inlet of preflotation induces an important increase of extractives. Although postflotation can remove up to 15% of the stickies of the inlet, the overall effect observed is a stickies[11] increase around 25%.

On knowing that the small size stickies, which are not affected by screening, are best removed during flotation, their removal in postflotation, performed after a dispersion step, should be more efficient than in the preflotation step, in which the stickies are larger.[25] However, both the present and previous studies[10,11] evidenced a higher efficiency of preflotation, comparatively with postflotation, in removing stickies.

Stage 7. The final thickening steps (disc filter 2 and press screw 2) removed, on average, 44% of total stickies content. Literature data show that, since the outlet of postflotation to the final pulp, stickies were removed in ratios of 15.9%[10] or 39.1%[11] as due to a washing effect. Disc filter 2 appeared as a very efficient stage in total stickies removal (at an average value of 55%). However, in the sequence press screw and medium consistency pump (MC pump) (end of pulp line), the stickies content recorded an average increase of 23%, due to the dilution process, from 16% consistency to around 6-7% with the white waters from the paper machine.

Thickening has a great effect in the reduction of extractives in pulp, while dewatering of pulp induces the inlet of a considerable quantity of extractives to the water loop with the filtrate. The filtrate comes again into repeated contact with the recycled fiber pulp, mainly as dilution waters, being a constant source of stickies when the water is reused without any further treatment.[8,27,30] Modern microflotation, pressurized filtration and membrane filtration technologies can be used for avoiding such situations.[15]

CONCLUSIONS

The total content of stickies, measured as dichloromethane extractives, is removed up to 80%-90%, by stock preparation processes, depending on the initial stickies level. The first loop is the key to a high stickies removal. In both surveys, a 72% reduction of stickies is achieved. The second loop produces a further removal of 9% (in the case of a high level of stickies in the line) or of 19%, respectively (in the case of a regular level of stickies in the line). The process stages producing a higher stickies removal are the first flotation and the second thickening stage.

Although, in both cases, the results obtained showed a high efficiency of contaminants removal (80-90%), the residual stickies levels at the end of the line are very different (a double initial stickies content causes a four-time higher stickies content at the end of the line). A linear correlation between the initial level of stickies at the beginning and at the end of the line is found and corroborated with other published results, which shows the importance of the quality of the raw material once the line is optimized.

The dilution steps induced an increase of stickies content, therefore further water treatments are necessary prior to water reuse to reduce stickies level in the final pulp.

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