A state-of-the-art deinking Separation process for maximum yield

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ABSTRACT

Papermaking line is an integrated system where the success of subsystems following each other, depends on success of previous stages. In the beginning of whole integrated paper making line the paper making potential of furnish is generated or "recovered" in the case of recycled fiber. "Recovering" means separation of impurities from the valuable fiber and mineral material and refreshing the properties of fiber material by mechanical and chemical means.

Impurities in waste paper are complex mixture of compounds where composition and share of impurities varies uncontrolled way. Impurities can be "classified" according following: heavy coarse particles, plastics, smaller heavy particles, ink, dirt specks and stickies. Deinking process is relative complex system, where each deinking unit process has a specific task in separation of impurities and cleaning of the pulp. In this paper deinking concept and system performance is approached from impurities, i.e. rejects point of view. Performance of deinking line unit processes and the cost of their operation are discussed.

1. All process areas are important in integrated system

Papermaking line is an integrated system where the success of subsystems following each other, depends on success of previous stages (figure 1). Raw material feeding must be quality- and capacity-wise stable.

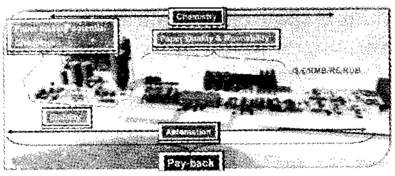

Figure 1. Papermaking line is an integrated system.

Ink must be well detached in slushing stage to enable ink removal in flotation stages. Coarse rejects must be removed to enable good runnability in fine screening. Stickies must be removed with maximum efficiency in fine screening. Otherwise risk for (micro) stickies accumulation to the DIP and PM systems increases. Flotation must remove detached ink, ash and hydrophobic impurities to give desired optical properties and prevent accumulation of these impurities to the DIP system. If flotation does not remove ink, neither will bleaching operate properly. Appropriate water management practices must be applied to keep colloidal impurities levels at control. Incoming water must fulfill certain quality requirement to ensure successful deinking. Mill's effluent treatment must ensure that no harm is made to environment. Sometimes when fresh water sources are limited, effluent water must be recycled back to the process without excess accumulation of impurities and COD to the system. Trend has been to reduce capacity of mill's internal water treatment in the name of investment and operational cost reduction at DIP plant. Hence, proper operation of flotation system has become more and more important. If DIP system does not produce stable quality pulp also in PM system will be instable. Variation in ash, freeness, ink, stickies levels and optical properties cannot be (completely) compensated in PM system. PM retention and runnability will be instable. This may cause instability in make-up water quality for DIP plant and even in pulp consumption, which both will affect to the DIP system operations. Impurities may require elevated consumption of PM chemistry increasing operating costs. Still, there might be caused irregularities in PM maintenance shut-downs for press section fabrics changes, cleaning at drying section, calendar rolls and so on. In worst case, decrease of printing machine runnability and quality of printing tell that there is something to be optimized in integrated papermaking line.

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2. Optimization of separation unit processes yields optimization of energy consumption and yield losses

Though investment-wise furnish manufacturing, i.e. recycled fiber plant and stock preparation plays minor role, it is the key area where basis for successful papermaking and paper quality is created. In the beginning of whole paper making line integration the paper making potential of furnish is generated or we say "recovered" in the case of recycled fiber. "Recovering" means separation of impurities from the valuable fiber and mineral material affecting positively to targeted paper properties.

During the life-cycle of paper product, paper making components are mixed with various compounds from paper converting and other adding-value processes in pre-consumer phase and with various contaminations in consumer and post consumer phases. These additional compounds are regarded as "impurities" in re-processing of furnish for the next round's end product. Each end product has certain quality targets (regarding brightness, dirt and stickies amount) to be fulfilled. By knowing the raw material features and end product requirements a deinking process is designed. Today, both investment and operational costs are of the highest importance without forgetting the environmental effects.

As there are various types of impurities to be separated, various types of separation technologies need to be applied. Table 1 summarizes the technologies and also shows the"costs", i.e. typical values for total losses, good fiber losses and energy consumption. These values are"typical" as the raw material quality has major effect on these values. In principle, the dirtier raw material is, the higher losses and energy consumption are. Hence, the origin of recovered paper (pre/post consumer), collection system (mixed/sorted) and stable sourcing affects the treatment costs.

It should be noted that though applied

Table 1
Deinking line impurities, tools and separation costs

Impurity	Tools (sub processes)	Cost per sub process group
Heavy coarse particles (glass, metals and stones)	Pulping, HC-cleaning & coarse screening	RRm~2...3% Good fiber loss~0.5...1% Energy~25...30 kWh/t
Plastics	Pulping & coarse screening	See above
Small heavy particles (sand, glass)	Cleaning	RRm~0.5...1% Good fiber loss~0.2...0.5% Energy~15...35 kWh/t
Ink	Pulping, flotation & dispergation	RRm~14...20% Good fiber loss~1.5...2% Energy~90...120 kWh/t
Dirt Specks	Pulping, flotation & dispergation	See above
Stickies	Pulping, screening & flotation/micro flotation	RRm~15...22% Good fiber loss~0.5...1% Energy~70...80 kWh/t

technologies mentioned have their main task, they often contribute to separation of various impurities. This means that if for some reason some process stage fails, other unit processes may partly compensate reduced efficiency in preceding process stage. This is quality-wise good but may lead to cost-wise non-optimized operation. Another aspect is that accurate evaluation of energy consumption per impurities type is difficult. Further, in most applied separation technologies energy consumption is not directly related to impurities amount. Dominating factor for energy consumption is how and in which consistency pulp suspension is treated and fluid dynamics are controlled. Hence, best approach to reduce energy consumption of the deinking system is to define appropriate cleanliness level for pulp quality, corresponding end product and customer requirement. For specified quality, requirements one must find raw material that has required quality potential. Typically, the more raw material quality deviates from target quality, the more treatment stages are needed and the more losses will occur. For future unit process development point of view efforts should be focused on maximizing efficiency of applied unit process and by that way reducing number of required treatment stages.

3. Separation tools to remove impurities

3.1 Heavy coarse particles and plastic removal

There are two main principles when designing a deinking line. First, impurities must be made into "separable form" with minimum break down and with minimum energy (kWh/t). Secondly, impurities should be removed at early stage and as big as possible with maximum selectivity/minimum good material losses and energy. Finally, residual impurities should be made non-harmful by mechanical or chemical means. At the beginning of deinking line coarse and heavy impurities are removed. First unit processes, i.e. slushing, HC-cleaning and coarse screening are responsible about heavy coarse particle and plastic removal. These unit processes act as a buffer part for rest of the process and success of these unit processes has a major effect on runnability and performance of forthcoming process stages.

Both HC-batch pulping and continuous drum pulping technologies have been applied for slushing. Drum pulper has proven to be the gentlest tool for waste paper slushing, still giving excellent ink detachment for all type of raw materials when properly dimensioned. So, drum pulper is applicable to all type of raw materials for DIP line capacities down to ~200 tpd. In smaller lines the pay-back time by energy saving is typically so long that it is not anymore so attractive for decision makers. From rejects point of view, the main aim for slushing reject quality is minimum fiber losses. Typically, slushing rejects are collected separately from other deinking line rejects. Sometimes rejects are pressed to a higher consistency for minimization of transportation costs. As the composition of pulper reject is very inhomogeneous, the utilization of reject is challenging. It would require further treatment and separation of components that could have further value in some other application.

Slushing is followed by 1- or 2-stage HC-cleaning. Good performance of HC-cleaning is critical for minimization of wearing in screening processes. When system is properly dimensioned and operational parameters (flow, pressure drop over cleaning) are correct, the cleaning efficiency is relative good and reject of HC-cleaning is free from fiber material. Typically, there is no further value for utilization of this reject. In HC-cleaning position major focus has been designing cleaners equipped with cone

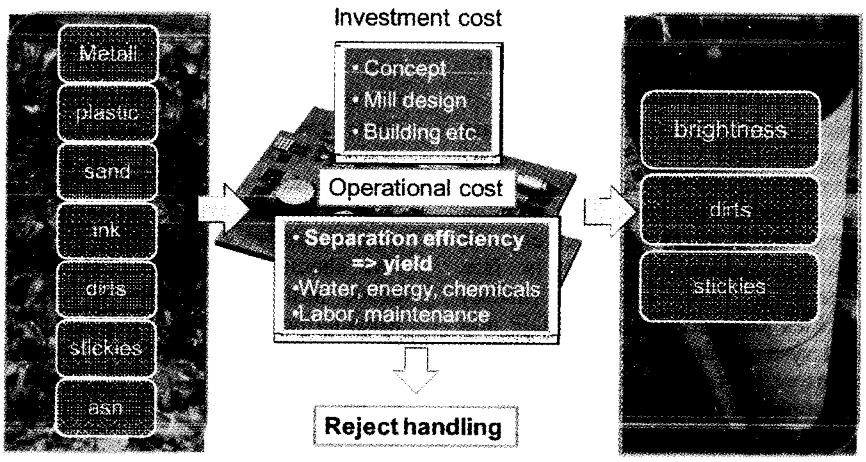

Figure 2. System design principle

materials that tolerate abrasive impurities. Typically, ceramic or powder metal materials are applied. Depending on heavy reject load and operation sequence, the HC-cleaning valves operate up to half a million times per year which sets major challenge for valve and sealing materials.

HC-cleaning is followed by coarse screening which completes plastic and heavy particles removal. Flow simulation was used as a major tool when designing new ProCS screen equipped with rotating basket technology. Rotating basket is typically equipped with 2 mm holes and profiles surface. Operation principle deviates from conventional rotor technology. Advantages of ProCS screen is good runnability without plugging, low energy consumption and long life-time for screen baskets. In coarse screening as well as in MC & LC fine screening equipped with slotted baskets addition of process stages enable to concentrate the reject and to minimize the good fiber losses. ProCs-screen can be equipped (typically 2nd or 3rd stage) with LiteFlow unit to improve removal of light reject (Styrofoam, plastics, etc.).

Coarse screening is typically 2- or 3-stage system and in fine screening 3 to 4 stages are applied. The applied number of stages depends on production capacity of the system and also how screens have been dimensioned. The required number of stages must be calculated based on expected yield saving and quality vs. investment and operational costs.

Many cases reject from coarse screening can be treated together with rejects from forthcoming process stages. However, coarse screening reject may contain significant amounts of plastic residuals. Deinking sludge/rejects can be burned, but in standard boiler system chlorides originating plastics may cause corrosion problems and hence, are not allowed in boiler fuel. Deinking reject sludge can be also considered as "fiber-clay" material and can be used for soil improvement. In some areas no plastic residuals are allowed in fiber-clays and hence, coarse rejects must be treated separately.

3.2 Small and heavy particles

In the beginning of deinking lines coarse reject removal section, process consistency typically is > 3%. Hence, separation efficiency of smaller heavy particles is limited. Typically, deinking system is equipped with LC-cleaner plant. There are several options

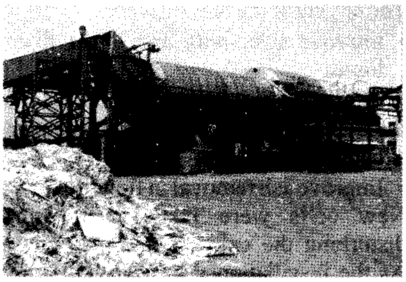

Figure 3. Drum pulping for coarse reject removal

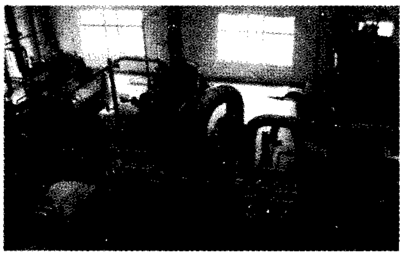

Figure 4. Coarse screening for coarse reject removal, cleaning for small sized heavy particles removal and fine screening for stickies removal.

regarding the location of LC-cleaner plant. In printing and writing paper line common practice is that there is complete LC-cleaner plant in PM short circulation. The search for reduced operational cost has created process solutions that should be evaluated when new line or system improvement is designed.

If raw material is relatively clean from heavy particles, there are mills where no separate full LC-cleaner plant has been applied. Some more wearing might occur but still, the saving in operational (pumping) costs may cover somewhat shorter rechroming sequence of baskets. Hence, this option should be attractive for standard newsprint lines. In some lines cleaning is not applied at all, but correspondingly in some lines cleaner plant has been added afterwards as the raw material quality has significantly deteriorated. Once again, knowing the raw material properties/quality and keeping it stable is highly important.

Traditional concept is to have cleaner plant after main flotation stage where it gives protection for fine screening system and operating consistency is beneficial for efficient operation of cleaners. Typically, this location yields to decrease of the pulp consistency, increases pumping costs and correspondingly increases the hydraulic load for thickening (disc filter) stage. Cleaner technologies equipped with bottom and/or intermittent dilution enables to apply cleaner plant before main flotation stage in a range of 1.4...2% consistency. This technology gives good sand separation efficiency with fewer amounts of cleaners, reduced amount of fiber losses and with lower pumping costs (flow).

Further simplified and advanced option is to apply primary fine screening in elevated consistency ~1.5% and use it fractionation type stage and then apply cleaner plant on "side" line with reduced feed flow still giving good small heavy particle removal.

However, for high brightness (> 80 ISO) and maximum cleanliness (minimum specks) products, cleaner plants are applied as a standard solution though pumping costs are high. In these application, it is recommended to utilize cleaner technologies with narrow diameter and possibly, also at elevated pressure loss levels.

Cleaning efficiency for small sized heavy particles has been reported to be very good (> 90%), even at elevated consistencies. Sufficient amount of cleaner stages ensure relatively low total losses. Good specks and stickies removal can also be achieved, but then elevated pressure losses over cleaners and reduced operating consistencies are recommended.

3.3 Ink and dirt removal

Ink and dirt removal affects the most on visual cleanliness of the pulp and applicability of the pulp for different paper grades. Hence, for separation the costs for these impurities are also the highest. For older deinking systems, it is rather typical that design production rates have been exceeded. During the operating years, the raw material quality has also deteriorated from design values. As ink and dirt removal is key and costly area of recovered paper processing, in this area has been done also a lot of development work. Quality performance vs. energy efficiency in this process area has significantly improved during last decade.

Key technology for deinking system quality resulting "true removal" of ink and dirt is flotation. Key technology for system operational costs is also flotation. Flotation key dimensioning principle is that enough air at proper form (bubble size distribution) is mixed with the pulp at applied retention time. Typically, in rotor aerated technologies air-to-pulp ratio is lower than in injector aerated technologies. Hence, rotor aeration requires longer retention time than technology with higher air-to-pulp ratio. In both technologies control of bubble size distribution and air amount have proven show major effect on flotation performance, its selectivity and also on reject properties.

Metso has launched new OptiCell LCA flotation technology based on injector aeration (figure 5) which has many new features, but utilizes also some of the good features of previous flotation technologies. The OptiCell flotation cell is optimized in every respect. Based on computational fluid dynamics, its elliptical and linear shape provides an excellent basis for smooth flow velocities, which allows the maximum quantity of bubbles to rise and enables efficient froth removal. The new linear cell structure ensures that the bubbles conveying the ink rise without trouble, resulting in high ink removal. The linear cell structure has a large surface area, which has a positive effect on reject separation and fiber loss. The new cell design also contributes to high sludge consistency by ensuring smooth froth drainage. In addition to the new cell structure, another up-to-date feature in OptiCell is accept channel, which was optimized with the aid of fluid dynamics. The accept channel is designed to deliver an even flow from each injector section to pump suction. A generous reject channel, in turn, allows the reject froth to exit smoothly from the cells. In the new cell, there is a head box that feeds flow to the injectors. In this way, injectors do not need their own pipes. Less piping leads to space savings.

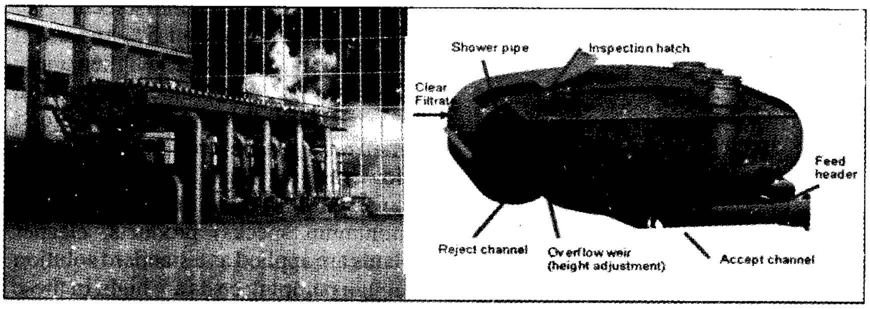

Figure 5. Flotation for ink removal

The first LCA-flotation at mill was started on September 15th, 2008 in Germany. Delivery comprised a new pre-flotation primary cell "Street 3" parallel to the existing old cells (two times 7 primary + 2 secondary cells) and new secondary stage cell (common for all pre-flotation primary cells) designed for 158 t/d capacity. The rebuilt pulp line manufactures deinked pulp for SC (super calendered) paper.

The targets of the rebuild were:

- improve selectivity and lower fiber losses
- improve brightness increase in flotation => savings in bleaching chemicals
- Improve ash removal in flotation.

New cells were installed without disturbing the existing line operation. As the installation was ready, missing pipelines were connected, new control programs were run and system was started-up.

The start-up was very successful, both operational and quality-wise. The cell started up just as easily as pressing a button. The brightness from the complete flotation system has increased by 2 units. A brightness gain of 13 units from thick stock to accept was achieved in the rebuilt process. Also reject ash content improved and fiber losses decreased. As a result of the flotation brightness improvement, peroxide consumption decreased (~half) in bleaching. As the new cells "healed" the system that has also helped to tune existing cells for better performance and offered possibilities for further savings in energy.

Figure 6 shows two examples of flotation reject, i.e. Flotation sludge composed of ink, dirt specks, stickies (mainly micro-stickies), 60...75% of ash and some good fiber losses. Both cells are working well, but on left side 2-stage system reject (Cs ~2...2.5%) overflow is more generous enabling flexibility in raw material quality. Secondary stage will limit the losses (sludge Cs. 3...4%). On left side 1-stage system overflow is limited, which yields high reject consistency 5...6% but risk for backflow of impurities to accept side.

Besides flotation, dispergation is a key technology for overcoming quality deteoriation caused by dirt specks. Dispersion stage has caused a lot of debate. The fact is that it is the major source of energy consumption in deinking line. Investment costs including thickening and pressing stages are also high. However, it has major effect on visual outlook of the pulp without losses (if the effect of bleaching on yield is excluded).

Conical disperger technology gives major advantages. This technology features large filling processing area with large nbr of "action teeth". It has optimal shape of fillings structure for pulp transportation through the treatment zone without risk for"pulp escape" by centrifugal forces. Further, it features possibility to design dispergator performance for impurities removal (specks removal efficiency up to 85%) and also extend the dispergator effect also on fiber development (+10...20% tensile strength), i.e. HC-refining effect without fiber cutting.

Based on mill and pilot plant studies following observation about dispersion performance has been made (table 2). The table can be summarized following way. Up to 50...60 kWh/t is enough for maximum ink detachment and specks dispersion. Energy levels above that yield extended fiber development (strength improvement). Dispersion temperatures > 90 C are beneficial both for stickies removal and bleaching efficiency.

3.4 Stickies removal

Ink and dirt specks have major impact on visual outlook of the paper. However, the most important factor for efficient high speed paper making is efficiency of stickies removal and

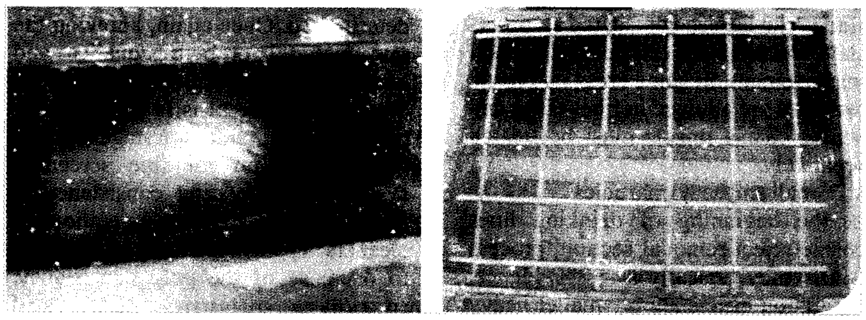

Figure 6. Reject from 2- (ONP/OMG) and 1- (SOW) stage flotation systems

Table -2
Recommendations for dispersion energy

Task for DIP dispersing	SEC Recommended, kWh/t	Comment
Ink detachment	25...50	Higher SEC causes ink fragmentation. Consistency should be >20%.
Reduction of dirt specks	30...60	Dirt break-down improves with high number of impact zones in the fillings
Reduction of stickies	40...80	Temperature >90 C is essential. Incoming stickies content should be >150 mm^2 /kg.
Softening & curl	25...40	For Tissue. Curl improves in high consistency. High SEC drops CSF and softness.
Improvement of strength	40...80	Tensile can be increased until tear deteriorates.

making them non-harmful. Unfortunately, the nature of stickies (compositions and size ranges) has made the reliable analysis of sticky material removal and its correlation to PM operations challenging. There is still a lot of development work to do in analytical methods. Some new stickies analysis methods combined with advanced mathematical approaches have shown promising correlation between total stickies amount in PM process waters and PM runnability.

Stickies removal is one (key) area of stickies control/management. There are also other tools that must/can be used to minimize the negative effect of residual sticky material in system. Additional chemistry in stock preparation area and runnability tools at PM completed by frequent washing shut-downs complete the tools used against sticky problems. The total costs of stickies are very difficult to calculate. The fact is that the cleaner is the pulp coming from DIP plant, the cleaner is the PM system and

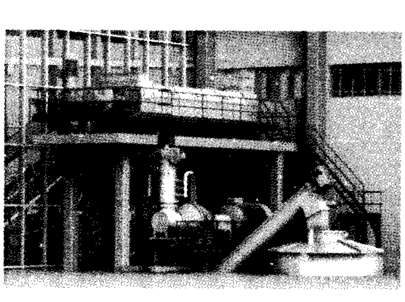

Figure 7. Dispersion for specks and stickies disintegration

less additional costs and instability in the system are created. Hence, no efforts should be compromised when maximizing the stickies removal efficiency before PM-system.

3.5 Reject handling & water management

It would be ideal if impurities not originating from paper manufacturing, converting and printing could be kept separated from paper recycling. Ink, coating components and "binding" materials (glues, staples), though their residuals are harmful for recovered paper properties, in rejects they are not necessarily harmful for secondary utilization of sludge in soil improvement, burning or even in special construction materials. Heat value of sludge for burning depends on ash (mineral) content of the sludge and its dry content. As for wood heat value is 14...20 MJ/kg and for deinking sludges it can be about half of that 7...10 MJ/kg. Coarse reject mixture glass, sand, aluminum and plastics are not possible to utilize without further treatment. There are technologies that can separate high heat value products like wood and plastics from metals and non-valuable residuals but this requires extra investment. So, besides for quality of the recovered paper and economy of paper recycling, properly operating paper collection chain is also important for environment.

In many areas even more important issue is paper making line water management. This includes how much water is used per produced ton of paper and also the quality of mill's effluent waters. Typically, there is local legislation giving limits for water consumption and also quality of effluent waters. When effluent waters are used for irrigation, limits are even more strict. There are chemistry tools that can be used to limit e.g. sodium load in effluents. The chemistry related possibilities are limited and may lead to compromised in system operation. There are also advanced cleaning technologies available like membrane technologies (nano), reverse osmosis and evaporation technologies that can ensure the quality targets for system internal and also effluent water qualities in all situations. Once again, careful studies about local conditions and economical limits must be made when right solution is chosen.

4. Conclusion

Papermaking line is an integrated process where success of following process stages depends on success of previous process stages. Deinking process is a separation process where impurities are separated from the valuable fiber and mineral materials affecting positively to targeted paper properties.

There are two main fundamental principles for deinking separation process design. First, impurities must be made to separable form with minimum energy and with minimum break downs. Secondly, the impurities must be removed at as early stage and as big as possible with maximum selectivity/minimum losses and energy

These tasks are executed in deinking process through innovative unit process technologies like drum pulping, efficient coarse and fine screening, high and low consistency cleaning, pre and post flotation stages, conical dispersing. Efficient operation of unit processes requires practical process solutions, adequate water clarification and rejects handling processes.

In new lines latest knowledge regarding unit processes and process concepts are applied. In existing paper making lines excess capacity triggering bottle-necks or out-of-date technology related capacity/yield and quality problems can be solved by well focused process improvement/rebuild.