Potential of refining and dispersing to develop recycled fibre properties

By C. Le Ny and M. Messmer

Abstract: The performance of recycled fibres (RCF) refining has been characterised as fibre peeling and cutting, external & internal fibrillation, fines generation, curl and kinks removal. In addition to less fibre cutting, the specificity of High Consistency (HC) versus Low Consistency (LC) refining is internal fibrillation. Disperser performance differs from refiners due to fibre curl and kinks generation. As expected, LC refining improves paper surface smoothness, gloss, porosity and tensile, at the expense of bulk and tear. On the other hand, HC technology offers more possibility to develop strength properties.

For economical and environmental reasons, the use of recycled fibres (RCF) has seen a significant development in printing paper grades, especially Magazine papers in recent years. RCF shows a high potential in Super Calendered (SC) grades due to the contribution of fillers and chemical pulp providing competitive gloss, oil absorption, brightness and strength. On the other hand, some limitations have been reported in light scattering, compressibility — bulk and surface properties, as well as a certain sensitivity in Rotogravure printability. Compared to a standard RCF process for Newsprint, RCF line for Magazine grades usually includes some of the following stages: postbleaching, second dispersion, refining and washing.

One of the expected benefits of postrefining is to enhance fibre structure so that paper surface and absorption properties together with tensile strength would be improved with limited effect on drainage, bulk and tear strength. For that purpose, different technologies are available, among them High Consistency (HC) refining, Low Consistency (LC) refining and dispersing. Since the main function of dispersion is to improve pulp cleanliness via stickies and dirt specks fragmentation, there have been limited studies on its influence on fibres properties. Furthermore, as recycled pulp is produced from a mixture of old magazines, old newspapers and office papers, it contains varying amounts of chemical and mechanical fibres with different refining requirements if any. Therefore, it is particularly difficult to predict the behaviour of one recycled pulp during refining and select the optimum technology and conditions.

This paper is based on a comparison of industrial equipments performances, at fixed operating conditions, in three RCF mills. One objective of the study is to clarify the potential and limitations of different mechanical treatments to upgrade recycled fibres. Since the operating conditions vary from one mill to another, no absolute comparison of the technologies is possible. Instead some general tendency can be proposed for further study.

The conventional method to study the effect of refining on pulp quality is usually limited to the measurement of freeness, fibre length, strength and air permeability. Since these results reflect the combined effects of various fibre changes, their contribution to the understanding of basic phenomena at fibre scale is quite limited. There is a real need to develop methods to identify the major changes in fibre structure occurring during refining and dispersing [1]. In this study, advanced fibre analysers have been used to characterise fibre cutting and peeling, fibre collapsibility, external and internal fibrillation, fines generation, curl and kinks.

Methods and Materials

All together twelve recycled pulps were sampled at the inlet and outlet of different refining & dispersing systems located in three European deinking mills. The operating conditions were as during normal production. Recovered papers composition was similar in the three mills: 50% old magazines, 45% old newsprint, 5% office papers.

Computerized sheet former M/K Series 9000 with white water recirculation and addition of fresh fillers clay was used to produce 30% ash content sheets, at 52 g/m². The steps of Robot sheetmaking are sheet formation, wet sheet transfer to press felt, pressing and drying.

Finally, the sheets were supercalendered with a laboratory device, developed by Gradek. The calender has one steel roll and one paper filled roll driven with a pre-set speed of 12 m/min. Temperature of the electrically heated steel roll was fixed at 60°C. Nip load and number was optimised in order to reach a PS10 level of 1.2 microns and density of 1150 - 1200 kg/m².

Pulp samples

A latency treatment has been performed on all twelve pulp samples in the following conditions: dilution with hot water 85°C to 2.2% consistency, disintegration for 30 000 revolutions. Preliminary analysis carried out to characterise the pulps composition show a chemical fibres — mechanical fibres ratio of 35% to 38% in the three mills.

Process conditions

Altogether five LC refiners, one HC refiner and one high energy disperser were involved in the study / Table 1.
Characterisation methods

Fibres and fines properties
In this study, Fibrillation index (Morfi) has been used as an indication of external fibrillation. Fibre cutting was based on fibre length reduction measured with Morfi, Fiber Lab and Fibre Master. Fines generation was calculated based on fines content (Bauer Mac Nett < 200 mesh minus ash of the fraction). Fibre peeling could be identified with a decrease in the Cell wall Thickness (SEM) and fibre width (Morfi, Fibre Master). Cell wall Thickness increase together with increasing amount of fully collapsed fibres (SEM) has been used as an indication of internal fibrillation / delamination of fibre wall, swelling towards the lumen.

Finally, curl index (Morfi, Fibrelab) and the percentage of kinked fibres (Morfi) were selected as indicators of changes occurring to fibres “longitudinal shape”.

SC Robotsheets properties
The quality of 100% RCF SC Robotsheets, 52 g/m² at 30% ash content was evaluated based on ISO Standard.

RESULTS AND DISCUSSION

Impact of refining and dispersing on recycled fibre properties
Figure 1 summarises the main effects of HC, LC refining and dispersing on fibres structure. The results are expressed as percentage of effect calculated by

\[ \text{Effect(%) } = 100 \times \frac{(\text{Inletvalue} - \text{Outletvalue})}{\text{Inletvalue}} \]

Fibre peeling, external and internal fibrillation, fines generation and fibres curl and kinks removal have been expressed as positive values and fibre cutting, curl and kinks increase as negative.

Since LC refining is mainly based on fibres to bar interaction, shear forces are predominant on compression forces. As a consequence, primary effects of LC refining are external fibrillation, fibre peeling and cutting, fines generation, curl and kinks removal. When LC refining was performed at high energy, it was observed that external fibrillation, curl removal and fibre cutting were more pronounced. In previous publications, moderate LC refining main effect has been described as a development of bonding ability and straightening of curly and kinky fibres [2, 3, 4].

During high consistency treatments, the main interactions are fibres to fibres and compression forces are dominating. One consequence has been identified as a partial delamination of fibre cell wall, so called internal fibrillation together with more or less increase in fibre collapsibility.

HC refining performance is quite comparable to LC refining but its effects are less pronounced: less external fibrillation, fibre cutting, fines generation and curl removal with limited fibre cutting were observed. Part of these results are according to Ljungkvist study which shows that with HC refining considerable fibre deformation occurs with less fines production and fibre shortening than in LC [5]. One unexpected result from the present work is the decrease in fibre curl also with HC refining. Previous work in that direction has lead to the conclusion that all HC treatments increase fibre curl [1].

High energy dispersing leads to a development of internal and external fibrillation with fines generation without fibre cutting. One clear side effect is the increase in fibres curl and kinks which can be detrimental for fibres conformability and paper smoothness. Anyway, the reversibility of curl should be further studied [6]. Several studies have shown that whereas LC refining
straightens fibres, dispersion creates curl into fibres [1, 2]. According to Kriebel [6], curl will be generated during treatments where sufficiently high forces act on fibres which are fixed and cannot escape these forces. So the consistency range above 20% is the most critical. Since high temperature favours fibre deformation, operating a disperser without pre-heating can be recommended to avoid fibre curl.

**RCF drainage and swelling ability**

No correlation was identified between decrease in freeness / Fig. 2 and Water Retention Value increase / Fig. 3. Nevertheless, it is clear that all mechanical treatments induce a decrease in freeness and increase in WRV, indication of improved swelling ability which is the main target of refining.

However, the benefit of HC refining over LC technology described by Weston and Guest [7] as a higher potential to restore WRV with less effect on drainage, isn’t confirmed in this study.

**Impact of refining and dispersing on 100% RCF based SC paper properties**

As expected, tensile index increases with refining due to improvement in fibre bonding strength, a consequence of external fibrillation, fines generation and higher fibre conformability / Fig. 4. Simultaneously, tear index decreases due to fibre cutting except with the disperser which offers the best strength development. The high strength development potential of dispersing was described in Kriebel work as a consequence of fibrillation and flexibility of the fibres [6]. As already shown by Koljonen and Heikkurinen, HC refining has a better potential to improve tensile with limited impact on tear [8]. In addition, the impact of the mechanical treatments on fibre curl may play a significant role. Indeed, curliness is expected to be harmful to tensile strength although it may assist tear. This phenomena would explain the increase in tear observed after dispersing.

Refining also improves internal bonding of the pulp which can be measured with Scott Bond [4].

All mechanical treatments studied significantly decrease the air permeability which is expected to be a benefit for full tone printability / Fig. 5. The clearest effect is obtained with LC refining due to cumulative effect of external fibrillation, fines generation and curl removal. Unfortunately this result is achieved at the expense of fibre cutting and decrease in tear and light scattering. HC refining effect on porosity could be mainly a consequence of improved fibre conformability due to curl removal and higher fibre flexibility.

High energy dispersing offers the possibility to improve all strength properties, including Tear and Stiffness, but deteriorates surface smoothness and gloss due to increasing curl and kinks.

**CONCLUSION**

Reliable fibre analysers are available to characterise the changes occurring to fibres during mechanical treatments. Furthermore, the possibility to produce Super Calendered (SC) paper in laboratory scale with representative conditions, permits to forecast the impact of identified fibre changes on paper quality.

In addition to widely studied effects of refining such as fibre cutting and fines generation, other changes more difficult to identify have been characterised: curl and kinks removal with refining and increase with high energy dispersing, external fibrillation, internal fibrillation with HC treatments, fibre peeling with refining. Based on this study, the performance of HC refining can be expected to come close to LC technology with limited effect on fibre cutting. In the conditions tested, the main differences were the lower intensity of HC impact on fibres, and the potential internal fibrillation together with increase fibre flexibility.

A disperser operating at high energy differs from refiners, mainly with its impact on fibre curl and kinks.

The results achieved at fibre scale provide valuable information to support the changes occurring to paper quality. The decrease in air permeability is due to the cumulative effects of external fibrillation, fines generation, curl and kinks removal and internal fibrillation. The increase in tensile is a consequence of external fibrillation and fibre collapsibility leading to an improved bonding ability. Tear index is affected negatively by fibre cutting and curl removal. The content in fully collapsed fibres will have a detrimental effect on light scattering.

PPS roughness is probably mainly influenced by curl and kinks. Improvement in gloss can be expected from increase fibre flexibility.

The overall influence of RCF refining on SC paper quality appears positive, with the exception of tear, bulk and possibly light scattering.

Apart from its possible negative effect on paper surface properties, a high energy disperser could be a promising tool to increase paper strength.

**RECOMMENDATIONS**

In addition to fibre length and fines content, measurements of fibre curl, kinks, width, fibrillation, and Cell Wall Thickness are recommended in order to follow changes in pulp by refining. A new method, less time consuming than SEM and image analysis should be developed to measure Cell Wall Thickness.

The choice between HC and LC refining for optimum development of recycled fibres is not very clear and may depend on the chemical fibre — mechanical fibres ratio as suggested by Pousi [9]. Therefore since recovered papers composition varies
widely from one country to another, the optimum technology may differ with the deinking plant location as well as with time.

The combination of HC treatment and LC refining in series could lead to a promising final result, as suggested by Fujita / Aikawa investigations in Japan [10].

Finally, a new technology should be developed to limit the detrimental effects of refining, mainly fibre cutting. Since it is clear that refining of fibre mixtures will never give the best development for either fibre [11], fractionation and selective refining of coarse mechanical fibres could show the way.

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Résumé: Nous avons caractérisé la performance du raffinage des fibres recyclées en terme de coupe des fibres, élimination de la paroi, fibrillation externe et interne, création d’éléments fins et diminution du curl et des coudes. La spécificité du raffinage haute concentration (HC) par rapport au raffinage basse concentration (LC) est la fibrillation interne et une coupe de fibre limitée. Un disperser diffère d’un raffineur de part l’augmentation du curl et des coudes. Comme attendu, le raffinage basse concentration améliore état de surface du papier, brillant, porosité, résistance à la rupture, mais dégrade main et résistance à la déchirure. En outre, le raffinage HC offre plus de possibilités de développer les propriétés de résistance du papier.


Keywords: RECLAIMED FIBERS, REFINING, CONSISTENCY, FIBRILLATION, PAPER PROPERTIES.