IMPROVING THE COST-EFFECTIVENESS OF WHITE TOP LINERBOARD BASED ON RECYCLED PULP

KAI BLASIUS and ADRIAN MANOIU
PTS – Papiertechnische Stiftung, Heidenau, Germany

Received September 24, 2009

The objective of this research project was to minimise the costs of producing white top linerboard. On the one hand, this was achieved by tapping cost-effective recovered paper grades so far rarely or never used as fibrous raw materials for white top testliner. On the other hand, production costs have been reduced, while the fibrous raw materials remained at a constant level, by implementing a concept for controlling the grammages of the individual plies.

In a first stage, several recovered paper grades were extensively treated at a laboratory and pilot scale, the treatment being specific for each and every recovered paper quality. The obtained results were used to calculate the requirements for the individual layers and for the entire testliner sheet, by using a simulation tool developed by PTS. This means that simulation allows testing of the different recovered paper grades and determining of their possible utilization as a fibrous raw material in the production of white top linerboard. This tool also permits to create combinations for pulp blends for the top liner and undertop ply in the testliner, which comply with the required quality parameters on the optical and strength properties.

Keywords: recovered paper, white top linerboard, product costs, pulp blending, simulation tool

INTRODUCTION

The paper products for packaging materials are manufactured largely on the basis of recovered paper. Either short fibre pulps or recovered papers of medium and higher grades are used to manufacture the white top plies of multi-ply testliners.

The purchase price of short fibre pulps is higher than that of recovered papers obtained from medium and higher grades. In addition, a high cost factor, *i.e.* that of refining to adjust paper strength, should be added to the equation. Higher quality recovered paper grades, with a volume of approx. 7% and thus the smallest market share (except for special grades), tend to accumulate as leftovers from the production and conversion of graphic papers. Accordingly, the production volumes are tied to this sector of the paper industry, having shown only moderate growth rates in the last few years.[1]

The continuously rising costs for energy and for the treatment and disposal of residues represent additional criteria that make it necessary to determine the marginal conditions that reduce the economic advantages of using recovered paper to produce secondary pulps with high brightness.

The state-of-the-art in recovered paper treatments has undergone many changes in the past few decades. The rising energy costs and the costs of pulp losses result from more stringent requirements and more complex technologies. In addition, the higher costs of chemicals are in turn linked to better cleaning efficiency and increased waste volumes.[2,3] The recovered paper market recorded severe fluctuations in availability, demand and price the last year, and especially in the current one. A constant rise in the prices of fibrous raw materials, energy, residue treatment and disposal is expected for the years to come. The material costs amount to approx. 44%, appearing as the most important factor in the cost structure of the paper industry. Similarly, energy costs amount[4] to approx. 13%.

The measures designed to reduce the specific costs of the fibrous raw materials for white top linerboard have the greatest potential for cutting the overall production costs. Thus, the project has the target of showing how and what raw materials should be used, as a function of the optical and strength properties. In addition, the existing possibilities for controlling the grammage of the top plies of the testliner product will be also demonstrated.

EXPERIMENTAL

The objective of the present research project was to minimise the costs of producing white top linerboard. This was achieved, on the one hand, by tapping the cost-effective recovered paper grades so far rarely or never used as fibrous raw materials for white linerboard, by a suitable treatment of recovered paper for the top liner and the undertop ply. At this time, stress was laid on maintaining the optical and strength properties of the testliners, as stipulated in the product specifications. These applications were compared with the costs accrued when current reference raw materials had been used, *i.e*. bleached commodity pulps, for the production of the top ply. The costs expected for an alternative pulp treatment were also evaluated.

Furthermore, while maintaining fibrous raw materials at a constant level, another objective was to reduce production costs by implementing a concept for controlling the grammages of the individual plies. This goal was achieved by developing a concept for reducing the grammages of the individual plies, while maintaining the specified total grammage of the paper. This means a sliding minimisation of the production costs for white top linerboard based on alternative grammages for the top and undertop ply, while still achieving the required product properties.

Rarely or never used recovered paper grades, viewed as more cost-effective for the manufacture of white top linerboard, were determined from the known recovered paper grades (EN 643), based on economic and optical criteria. Moreover, the decisions were also based on the results of earlier research work[4,5] (Table 1). The raw materials replaced only those used in the top and undertop ply.

A standard short fibre pulp, used to represent all commodity pulps used in the manufacture of white top linerboard, was intended to serve as a comparison basis for characterising the alternative recovered paper grades. Brightness, opacity, printability, bursting strength and short span compression strength were selected as the decisive features for white top linerboard. Suitable recovered paper grades were selected on the basis of these parameters, among others. The basic characteristics of the individual fibrous raw materials were classified to ensure reproducibility and comparability of the recovered paper to be treated. The values obtained were then used in the subsequent treatment steps and variations during pilot trials.

The treatment variations, selected according to the technological requirements, were based on the experience gathered in previously completed PTS research projects. In so doing, the process steps of pulping, screening, flotation, dispersing and bleaching were analysed selectively in different treatment lines. These findings, together with the results from the basic characterisation of the individual recovered paper grades, led to individual recovered paper treatment variations. The pulp treatment was then tailored to the requirements of the technical properties of the individual plies.

A prediction model created in the course of the project was designed to determine the individual ply weights for building up a multi-ply testliner with predefined brightness goals. The data from recovered paper treatment and the results of the pilot-scale tests served as the basis on which the simulation tool was created and calculated. The given total grammage of the testliner was controlled by varying the grammages of the individual plies. Varying the pulps in the individual plies in a technologically and economically reasonable way functioned to reduce the grammage of the cost-intensive plies, such as the top layer, for instance. Total grammage is preserved by increasing the grammage of the undertop ply, for example. The light scattering coefficient *s* and the light absorption coefficient *k* in different spectra (x, y, z, 457) were considered as characteristic values of the pulps in this Excel-based model. Since a linear correlation is assumed between the data after a process (y) and the data prior to a process (x), the coefficients of a linear model can be calculated by linear regression analysis. In addition, multi-ply structures were simulated based on the Kubelka-Munk theory.

Furthermore, the generated results were included as a basis for an economic feasibility test of the alternative fibrous raw materials. The quantification of the treated raw materials, as well as the characterised ply requirements, were put into practice on a PTS pilot paper machine. The best formulation for the top ply was prepared during the stock preparation of a reference mill based on laboratory and pilot trials. The values measured were then compared with the results obtained from model calculations for the applications investigated.

Once all work packages had been evaluated, a comprehensive analysis of the results was undertaken. Improvement measures and cost savings were demonstrated by evaluating the utilisation of the pulp potential and by determining the optimisation possibilities focused particularly on brightness and optical homogeneity.

RESULTS AND DISCUSSION

Basic characterisation and treatment variants

The individual fibrous raw materials had been pulped and screened and the initial brightness of the pulp pads was measured (Fig. 2). Brightness is cited once with UV (solid bars) and once without radiation (hatched bars). This makes it possible to differentiate between wood-free and wood-containing recovered paper grades, on the one hand, and between grades with optical brighteners, on the other. The samples in which optical brighteners had been used during production can be identified by their higher brightness values, which act visually to improve whiteness and, ultimately, brightness. The wood-free paper grades have significantly higher brightness values than the wood-containing ones, since the latter still contain lignin in the fibres. In addition, the potential of achievable brightness across the grade group can be estimated from the initial brightness value, depending on the type and volume of printability.

Table 1
Selected recovered paper grades

Recovered paper – grade identification	According to EN643
Sorted graphic paper for deinking	1.11
Lightly printed white shavings without glue	2.03.01
Sorted office paper	2.05
Tear white shavings	3.04
White wood-free letters	3.05
Multi-printing	3.10
White mechanical pulp-based coated and uncoated paper	3.15
White wood-free coated paper, without glue	3.16
White wood-free uncoated shavings	3.18.01

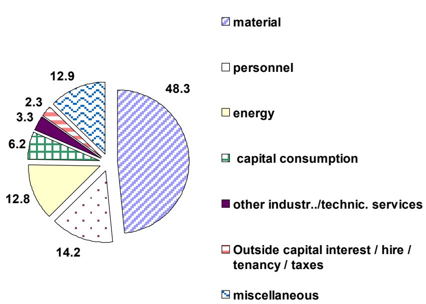

Figure 1: Cost structure of the German pulp and paper industry

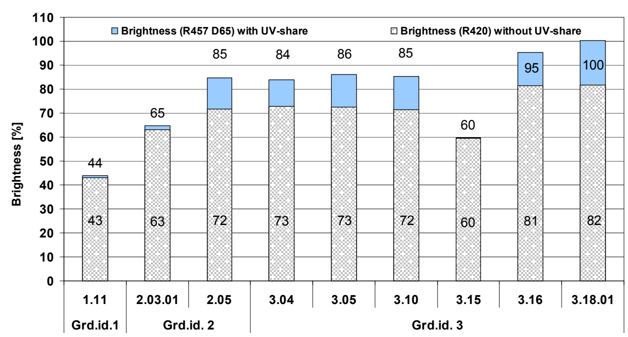

Figure 2: Brightness according to the steps of pulping and screening

Basic characterisation also involved measurement and evaluation of opacity, printing ink particle size and number, proportion of ash, SCT and bursting strength.

The next step involved defining the treatment variations based on the results obtained from the basic characterisation. In each case, the treatment variations selected for the printed recovered paper grades entailed a pre-flotation and a post-flotation unit. HC pulping was carried out for all printed recovered paper grades since, otherwise, the removal of the printing ink from the fibres would have been inadequate.

The selected results of the 2.05 “sorted office paper” raw material are illustrated below. Since the primary goal was to substitute the alternative fibrous raw materials for the top and undertop plies, the evaluations refer mainly to the optical properties. The process sequence (Table 2) according to the state-of-the-art for the selected fibrous raw material 2.05 was applied (variation 1), as well as a change in the order of the flotation/dispersing units (variation 2).

Figure 3 illustrates the increase in brightness across the individual treatment units. A good initial brightness value of 72% (without UV radiation) after screening is evident here. Similarly, the possibility of enhancing brightness by the use of optical brighteners is also shown. The increase in brightness of the two variations runs in a very similar manner in the first and second loops (1 and 2). Post-flotation and a second dispersing step, however, do not result in any significant increase in brightness. The influence of variations on printing ink particle distribution and removal is evident, however (Fig. 5). A two-loop treatment is advisable in any case when a fibrous raw material is used, since this produces a total brightness increase of 8%.

Figure 4 shows the discharge of inorganic constituents (coating pigments, ash) for both variations in configuration. Grade 2.05 is an uncoated paper grade, and therefore has a filler share of approx. 20% after pulping. If the filler content is too high (>20%), this may have negative effects on the strength properties of the new paper product, for example. The trial series showed that the discharge of inorganic constituents can be controlled by selectively designing the variations in configuration. A reduction of 4% is achieved in variation 1 with a single loop, as well as a reduction of 10% in variation 2. Another reduction, of 11%, was achieved in the second loop in V1, and of even 6% in the pulp in V2. This reduction in the second loop, however, had negative effects on opacity in both variations. In particular, the high losses due to the discharge of the coating pigments in post-flotation affect the reduction in the ash content. This discharge, however, also had a positive effect in that it increased the strength properties, leading, in turn, to variations in the average increase of 25% in bursting strength after one flotation. Attention should be drawn to the fact that, however, sufficient fillers are retained in the pulp, so that the addition and the costs of the new filler can be minimised, depending on the intended use of the new paper product.

Table 2
Treatment variations for recovered paper (RP) grade 2.05

		Type 1	Type 2
1-Loop system	1.0	pulping & screening	pulping & screening
	2.0	pre-flotation	thickening 1
	3.0	thickening 1	dispersing 1
	4.0	dispersing 1	bleaching (oxidative)
	5.0	bleaching (oxidative)	pre-flotation
2-Loop system	6.0	post-flotation	thickening 2
	7.0	thickening 2	dispersing 2
	8.0	dispersing 2	post-flotation
	9.0	bleaching (reductive)	thickening 3
	10.0		bleaching (reductive)

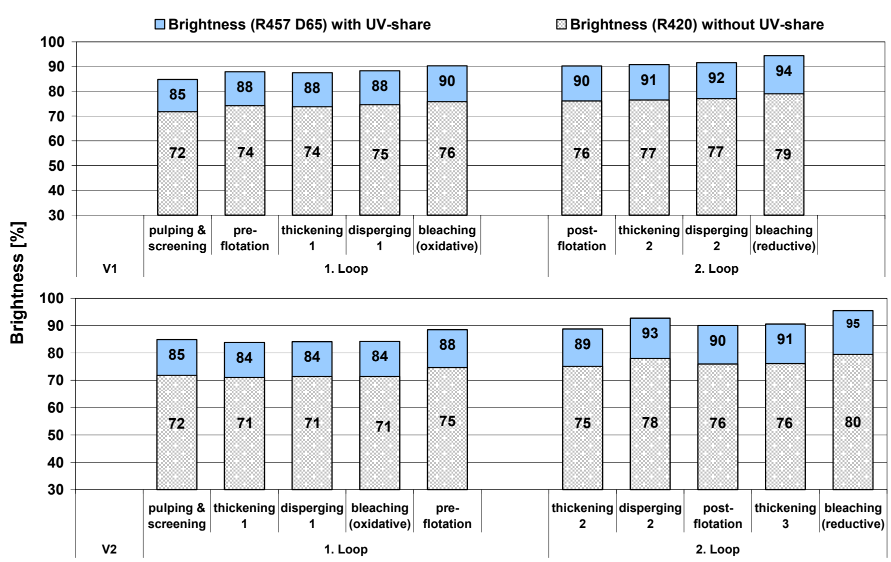

Figure 3: Brightness with and without UV radiation in treatment variations 1 and 2 of RP grade 2.05

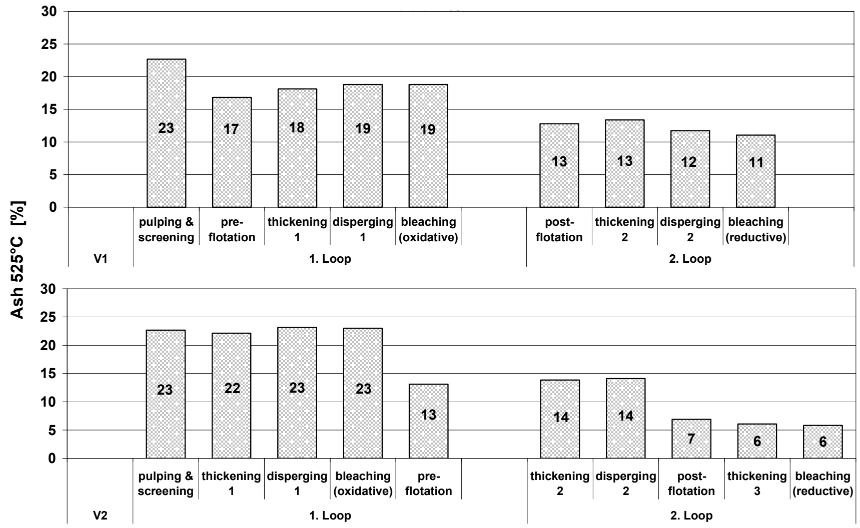

Figure 4: Ash content of treatment variations 1 and 2 of RP grade 2.05

The evaluation of the printing ink particle behaviour is shown in Figure 5. Grade 2.05 is a recovered paper grade printed chiefly using a laser printer. The diagram shows clearly that, in the case of grade 2.05, the treatment of the undertop ply can be considered as adequate in the one-loop system. If it is to be preferably used in the top ply, however, a two-loop configuration will be necessary to remove the printing ink particles.

It is worth mentioning that improved particle comminution and detachment can be achieved by reversing the order of dispersion and pre-flotation, since the ink particle area dropped by 87.6% after pre-flotation in variation 1. In variation 2, however, dispersion prior to pre-flotation attained a reduction between 8.768 mm²/m² and 183 mm²/m², corresponding to a reduction by 97.9%. Hence, if stress is laid on the area and number of printing ink particles, variation 2 is preferable to variation 1.

The results of the recovered paper treatment permit conclusions on the suitability of the grade as a fibrous raw material in the production of white top linerboard. It could be demonstrated that especially grades 1.11, 2.05, 3.05, 3.10 and 3.18.01 may be an alternative and may serve as possible substitution pulps for the chemical pulp currently used in the production of white top linerboard.

Raw material blend and costs of the individual linerboard plies

The values found make it possible to design raw material blends for top and undertop plies, for achieving the given brightness levels. A top ply brightness (without UV radiation) of 75% was selected to exemplify the individual plies of the three-ply linerboard. Treatment variations were chosen from the standard treatment (variation 1), implemented as a one-loop system = variation 1-1, and a two-loop system = variation 1-2.

Fibrous raw materials were defined for each ply quality to be investigated and for both treatment concepts. The pulps were selected from the recovered paper grades chosen, taking into account the brightness and ink particle values (area in mm²/m²) achievable by each treatment concept. The maximum ink particle area in the top ply was set at 150 mm²/m², and an ink particle area of 800 mm²/m² was assumed as a guiding value for the undertop ply, based on the state-of-the-art technology.

Depending on treatment variation, higher quality fibres from grade group 2 had to be added to the pulp obtained from recovered paper grade 1.11, to achieve a target brightness of 75% (without UV radiation). The most cost-effective way for achieving the desired brightness is the use of nearly 100% recovered paper grade 2.05. However, this grade has a large variation range as to the share of printed papers and paper qualities contained.

With an overall particle area of 354 mm²/m² and a total cost of 246.7 €/t, variation 1-1 is preferable to variation 1-2 (overall particle area of 100 mm²/m² and total cost of 296.0 €/t), however, the desired ink particle area cannot be achieved by its one-loop treatment process. For this reason, the two-loop treatment process (variation 1-2) is recommended – as mentioned before.

Table 3 lists the pulp formulations and the resulting costs for achieving a target brightness of 75%. The cost values, taken from the PTS database, are the standard values of a production plant typical for the industry in the year 2008.

By way of example, Figure 6 shows the ink particle areas and the production costs of a top ply for the given brightness levels. For achieving one and the same brightness level, the one-loop system is more cost-effective than the two-loop one, although it gives a larger area and a higher number of ink particles. It is also visible that ink particles influence the fulfilment of brightness requirements, when varying the composition of the fibrous raw materials.

Cost-effectiveness and pulp-specific grammage control of a three-ply linerboard

The production of a three-ply white top linerboard with an overall brightness of 70% (without UV radiation) and total grammage of 125 g/m² was chosen as an example from the range of possible ply combinations. Cost-optimized formulations served as a starting point for cost calculations. The brightness levels required for the pulp of the top ply were determined with a simulation model, taking into account the brightness of the undertop ply. A blend of recovered paper grades 1.02 and 1.04 was assumed for the back ply of the three-ply white top linerboard, representing common applications of these two grades.

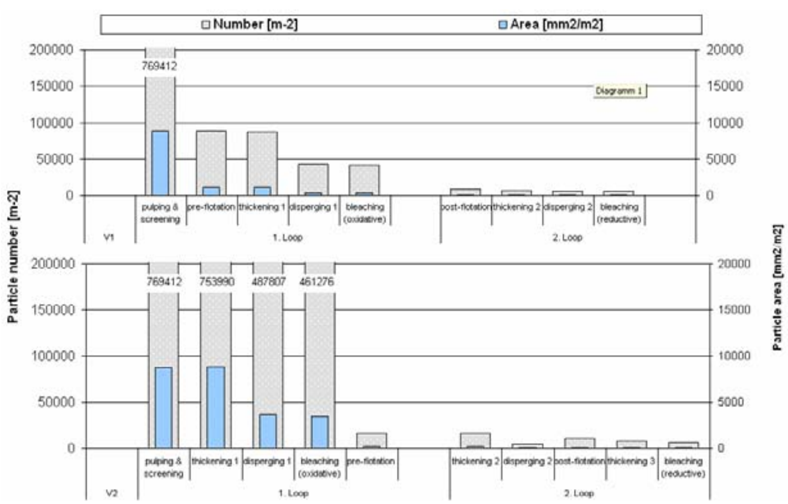

Figure 5: Number and area of ink particles in variations 1 and 2 of RP grade 2.05

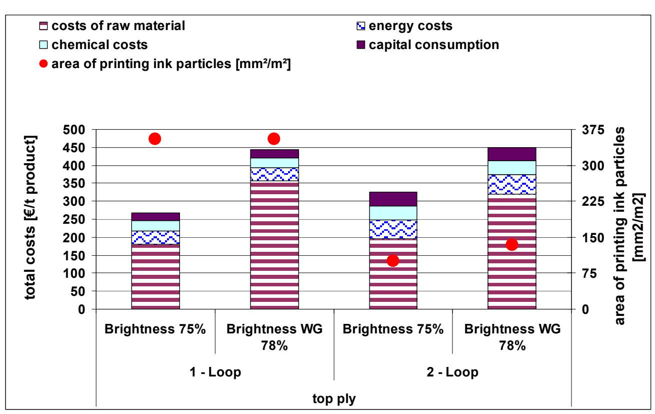

Figure 6: Total costs of the top ply – two-loop variation *vs*. one-loop variation

Table 3
Pulp formulation for 75% brightness and resulting costs

1-Loop-system (variation 1-1)					
Fibrous raw materials	Part of raw material [%]	Without UV radiation [%] raw material	Costs of raw material [Euro/t]	Loss [Euro/t]	Total [Euro/t]
Office sorted recovered paper	100	76	135.0	24.7	159.7
				Subtotal	**159.7**
Final brightness (without UV rad.) [%]		**75.9**		Energy costs	36.7
Area of printing ink particles [mm²/m²]		**354**		Chemical costs	27.8
				Capital consumption	22.4
			Total [€/t product]		**246.7**

2-Loop-system (variation 1-2)					
Fibrous raw materials	Part of raw material [%]	Without UV radiation [%] raw material	Costs of raw material [Euro/t]	Loss [Euro/t]	Total [Euro/t]
Newspaper & magazine	10	62	120.0	30.0	15.0
Sorted office paper	90	77	135.0	33.0	151.2
				Subtotal	**166.2**
Final brightness (without UV rad.) [%]		**75.4**		Energy costs	53.0
Area of printing ink particles [mm²/m²]		**100**		Chemical costs	38.6
				Capital consumption	38.3
			Total [€/t product]		**296.0**

Table 4
Linerboard ply structure: top ply, undertop ply, back ply

Indicators	Basic with pulp	1-Loop system	2-Loop system
Production per year [t/y]	90000	90000	90000
Grammage top-/ undertop- /back ply [g/m²]	45/-/71	22/22/72	22/22/72
Brightness: top-/ undertop- /back ply [%]	87/-/35	75/68/35	75/68/35
Total costs [Euro/t product]	261.6	168.0	188.0
Total costs [Euro/(t/y) product]	23544077	15120000	16920000
Savings for basic prod. [Euro/t product]	0	94	74
Savings for basic product per year [Euro/y/product]	0	**8424077**	**6624077**

Table 5
Comparative costs of white top linerboards with 70% overall brightness (without UV radiation)

Board	Structure, g/m²	Amount, %	Raw material	Brightness without UV radiation (%)	Total costs of preparation	
					Euro/t	Euro/t product
Top ply	22	25 75	RP-Grade 3 RP-Grade 7	79	602	106.0
Undertop ply	22	100	RP-Grade 5	62	310	54.5
Back ply	72	50 50	RP-Grade 1 RP-Grade 2	35	260	74.7
					Total costs	**235.2**

The white top linerboard chosen had the following characteristics: grammage of top and undertop plies amounting to 22 g/m², 80% brightness of the top ply and 60% brightness of the undertop ply. The recovered paper treatment agreed with treatment variation 1-2 (two-loop system). The total treatment costs shown in Table 4 include all costs arising from the raw material blend and are proportionally included in the total cost of the linerboard, according to their grammages. Once again, the cost values, taken from the PTS database, represent the standard values determined for a production plant typical for the industry in the year 2008.

The costs were estimated at 106 €/t paper stock for the top ply, at 54.4 €/t for the undertop ply, and at 74.7 €/t, respectively, for the back ply. The raw material blends required for achieving the brightness levels and target brightness were generated with a simulation tool. The total cost, including extras, of the three-ply white top linerboard with 70% brightness (without UV radiation) thus amounts to 235 €/t finished paper.

CONCLUSIONS

Finally, the total costs of the chemical pulp- and recycled fibre based linerboards, having an overall brightness of 70% (without UV radiation), but different top and undertop plies, were compared (Table 5). The table shows the three most cost-effective ply combinations of the recovered paper grades meeting the brightness requirements, compared to the reference (two-ply linerboard with chemical pulp in the top ply).

Assuming an annual paper production of 90000 tons, cost savings of the two-loop variation (grammage of 22 g/m²), as compared to the chemical pulp reference, were calculated at 6.6 m €/a. The 22 g/m², one-loop variation permits savings of 8.4 m €/a, but it must be borne in mind here that the high number of ink particles resulting from the use of more cost-effective fibres can make it impossible to achieve the desired optical product characteristics. Taking into account the possibly higher ink particle loads of office papers (2.05), the most cost-effective solution is the combination of the two-loop treatment process, with the top ply grammage of 22 g/m², top ply brightness of 75% and undertop ply brightness of 68%, as brightness distribution of the individual plies.

For the standard paper mill assumed here, cost savings amount to 6.6 mn € per year.

The conclusions of this project have led to a technological concept permitting high-white paper products to be manufactured cost-effectively from recycled fibres. The substitution of fibrous raw materials in the treatment of recycled fibre pulps for packaging paper production has two main aims: saving production costs, on the one hand, and varying the grammages of top and undertop plies whilst ensuring the production costs and product requirements, on the other.

The results obtained contribute to the development of technological methods to better utilize the raw material potential of the available recycled fibre pulps. This knowledge can now be applied at an industrial level.

ACKNOWLEDGEMENTS: The results were obtained in research project IW 073007 funded by the German Federal Ministry of Economics and Technology BMWi under the programme "Promoting research, development and innovation for growth drivers in less developed regions", co-ordinated by the company EuroNorm Quality Assurance and Innovation Management GmbH in Berlin. We would like to express our warm gratitude for this support. Our thanks go as well to the companies of the paper and supply sectors involved, for supporting the project work.

REFERENCES

[1] ***Papier 2009, Ein Leistungsbericht der deutschen Zellstoff- und Papierindustrie Verband deutscher Papierfabriken e.V. (VdP), Bonn, 2009.

[2] H. Schuster, E. Hanecker and K. Renner, *Vortrag beim Internationalen Münchner Papiersymposium 2003 – Fortschritte bei der Papierherstellung*, München, March 26-28, 2003.

[3] B. Carré and G. Galland, *5th Advanced Training Course on Deinking Technology*, Grenoble, Centre Technique du Papier (CTP), 2001.

[4] A.-M. Strunz, *München: Papiertechnische Stiftung (PTS)*, 58 S, PTS-Forschungsbericht PTS-FB 28/98, pp. 18-43.

[5] M. Klein, A. M. Strunz und G. Meinl, Forschungsvorhaben BMWA 1108/03; PTS 2005, pp. 1, 3 ff.