USE AND PROPERTIES OF RECOVERED PAPER RAW MATERIALS FOR THE PRODUCTION OF CORRUGATED BOARD*

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ABSTRACT

The difficulty of predicting the properties of paper products produced from heterogeneous sources puts several limitations, which therefore lead to severe economic losses and only a comprehensive characterization will enable their better utilization. The project "RF-CORRUG – Quality control of raw materials from recovered fibres for the production of corrugated board" under the National Strategic Reference Framework 2007–2013 ARCHIMEDES III deals with this common technical problem of the corrugated board industry. Specifically, the main objective of the project is to support the competitiveness of the corrugated board companies (mainly SMEs) by creating a software tool based on practical models that can predict packaging grade paper properties from fibre data (qualitative, quantitative, morphological) used in their production.

This paper presents information on the physical and mechanical properties of recovered packaging papers used in corrugated packaging. A number of different category papers (liners, flutings) used for corrugated board production in Greece were examined. The required paper properties included grammage, porosity, bursting strength, SCT, tensile strength and tearing resistance, and were measured by internationally recognized testers and standards. The data will be used to develop predictive models based on advanced statistical methods for the properties and performance of packaging according to information of their recovered raw paper materials.

Keywords: paper recovery, packaging grade papers, liners, flutings, recovered fibre sources, paper strength

1. Introduction

In the ideal case recovered paper would primarily be used for the manufacturing of the same grade of paper, i.e. newspapers for new newsprint, brown packaging papers for new packaging grades etc. depending on the availability of recovered paper and the collection systems used. This principle can however not always be fully applied; a certain mixing of recovered paper always takes place during the collection process. In recovered paper utilisation downgrading is always an option. This means that high quality recovered paper grades can be used in the production of "lower paper grades". On the other hand, it is difficult to use low grade recovered papers in the production of high quality end products; e.g. mixed grades cannot be utilized in printing & writing paper manufacturing. Clean recovered paper is, however, always a good raw material for the paper industry. With suitable collection and treatment technologies recovered paper can be utilized in nearly all paper grades (CEPI 2011).

In Europe, the new Waste Directive has partly minimized the threat of spreading the use of commingled collection systems to other countries in Europe and promoting the selective collection of all the recyclables, however, there is still a great controversy in the United Kingdom. The

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Directive is also expected to have an important influence on the quality of recovered paper available on the market through the “end-of-waste” criteria (European Commission 1994). Due to the potential benefits which can be expected by the recovered paper ceasing to be considered as waste (legal, economic, etc.), further efforts are expected along the recovered paper value chain to reduce total unusable materials to 1.5% or even less, the level required used paper ceasing to be a waste.

Improvement of sorting techniques has demonstrated to have a strong influence on the quality of recovered paper: today there is an around 30% reduction on average unusable material content of the recovered paper (from 11.9% to 8.11%). These advances can improve the quality of the recovered paper collected by commingled collection systems. However, the threat of contamination with non-paper components is still higher than in the case of source separate methods due to cross contamination. Quality is probably the major prerequisite for extending the use of recovered paper as a raw material, especially in graphic paper production. Papermakers claim for source-separated collection systems to achieve the necessary recovered paper quality needed to make paper recycling a sustainable process (Miranda et al 2011 & 2013).

The manufacture of corrugated board containers (boxes, trays, etc.) involves a production chain integrated by paper manufacturers, semi-elaborates (corrugated board) manufacturers and container manufacturers, the majority of which in Europe are SMEs. Nowadays, corrugated board containers are mostly manufactured with recovered paper. The greatest threat faced by the mentioned production chain is related to the lack of quality and availability of recovered paper as raw material. Specifically, one of the most important properties of packaging paper is its mechanical strength, which depends mostly on the length of the fibres of which paper is composed. These fibres are longer in virgin pulps (those coming from papers obtained from wood, i.e. not yet recycled). However, the high pressure on the demand - as well as the current economic and ecological restrictions in the use of forest based materials - has led to a situation in which very little quantity of virgin fibre enters the recycling chain. This means that the strength quality of recycled fibres - and by extension of the papers - is constantly decreasing with the on-going recycling cycles. In addition, recovered paper presents a very high variability, what constitutes an obstacle when it comes to manufacturing containers having homogeneous properties fixed by the customers at fixed costs.

2. Materials and methods

For this research, thirty two (32) papers from various origins were used. Sixteen (16) of them were liners (8 from *Brown kraftliner - KL* and 8 from *Testliner - TL*) and the other sixteen (16) of them were flutings-medium (8 from *Semi chemical fluting - SC* and 8 from *Recycled fluting – medium - RF*). Those papers represent almost all the possible type of papers produced in Greek recovered paper industry for corrugated board manufacture. The properties determined from those papers were the following:

Grammage, g/m^2: Grammage determination was based on ISO 536: 2012. For every case of paper, 20 specimens, each one with an area of 100 cm^2, were constructed and weighted. Grammage was determined from the equation:

$$w=10.000 \times \frac{m}{A}$$

W = Grammage
m = mass (g)
A = area, 100 cm^2

Air permeance -porosity, ml/min: Air permeance -porosity determination was based on ISO 5636-5: 2013. A special device which measures the time that 100 ml of pressured air (1,47 kPa) needs to pass through an A4 paper specimen was used.

Compressive strength (SCT), kN/m: SCT determination was based on ISO 9895: 2008. For every case of paper, 40 specimens were tested (20 vertical and 20 parallel to fiber direction) on a SCT tester. SCT was determined from the equation:

$$SCT = \frac{F}{W}$$

SCT = Compressive strength, kN/m
F = Maximum compression strength, N
W = Specimen width, mm

Tensile strength, kN/m: Tensile strength determination was based on ISO 1924-3: 2005. For every case of paper, 40 specimens were tested (20 vertical and 20 parallel to fiber direction) on a vertical tensile tester. Tensile strength was determined from the equation:

$$S = \frac{F}{wi}$$

S = tensile strength, kN/m
F = maximum tension, N
wi = Specimen width, mm

Tearing resistance, mN: Tearing resistance determination was based on ISO 1974: 2012 (Elmendorf method). For every case of paper, 40 specimens were tested (20 vertical and 20 parallel to fiber direction) on a Elmendorf device.

Bursting strength, kPa: Bursting strength determination was based on ISO 2759: 2003. For every case of paper, 20 specimens were tested on a Messmer burst tester.

3. Results

3.1. Physical properties

The results of physical properties determination are shown on Table 1. Brown kraftliner papers (KL) had the higher grammage and the lower porosity among all cases. All flutings-medium papers had generally higher porosity than liners.

Table 1. Results for physical properties[1]

Property	Liners		Flutings-medium	
	KL[2]	TL	SC	RF
Grammage, g/m^2	149.93 (26.23)	130.90 (26.71)	137.26 (18.33)	111.82 (13.50)
Air permeance - porosity, ml/min	294.76 (172.72)	328.87 (84.10)	389.99 (358.42)	581.56 (203.73)

[1] averages and standard deviations in parenthesis
[2] KL= Brown kraftliner papers, TL = Testliner papers, SC= Semi chemical fluting papers, RF= Recycled fluting – medium papers

3.2. Mechanical properties

The results of mechanical properties determination are shown on Table 2. Among all papers, brown kraftliner papers (KL) had the higher mechanical strength regarding all the mechanical properties measured. Brown kraftliner papers (KL) had also double tearing resistance than all the other papers. Semi chemical fluting papers (SC) had higher compressive strength (SCT) than all the other papers, and generally higher mechanical strength than recycled fluting – medium papers (RF). For tensile and bursting strength, brown kraftliner papers (KL) had the higher values compared to all papers while semi chemical fluting papers (SC) had higher values compared to recycled fluting – medium papers (RF) from flutings-medium category and compared to testliner papers (TL) from liners category.

Table 2. Results for mechanical properties[1]

Property	Liners		Flutings-medium	
	KL[2]	TL	SC	RF
Tensile strength kN/m				
MD[3]	8.72 (0.05)	7.17 (0.73)	8.38 (0.69)	6.99 (0.75)
CD	6.23 (1.38)	2.65 (0.80)	4.47 (0.95)	2.46 (0.28)
SCT kN/m				
MD	6.16 (1.60)	4.51 (0.83)	6.33 (1.98)	4.00 (0.77)
CD	3.44 (0.84)	2.44 (0.61)	3.53 (0.97)	2.18 (0.40)
Tearing resistance mN				
MD	151.32 (46.62)	64.64 (15.43)	61.51 (10.19)	68.05 (18.60)
CD	171.14 (67.20)	82.77 (7.61)	89.75 (16.15)	85.43 (9.84)
Bursting strength kPa	726.39 (129.73)	241.02 (42.78)	471.26 (149.59)	219.83 (32.76)

[1] averages and standard deviations in parenthesis
[2] KL= Brown kraftliner papers, TL = Testliner papers, SC= Semi chemical fluting papers, RF= Recycled fluting – medium papers
[3] MD=parallel to fiber direction, CD=vertical to fiber direction

4. Conclusion

- Brown kraftliner papers had the higher grammage and the lower porosity
- Flutings-medium papers had generally higher porosity than liners
- Brown kraftliner papers had double tearing resistance than all the other papers
- Among all papers, brown kraftliner papers had the higher mechanical strength regarding all the mechanical properties measured
- Semi chemical fluting papers had higher compressive strength compared to all the other papers, and generally higher mechanical strength compared to recycled fluting – medium papers (flutings-medium category) and compared to to testliner papers (liners category)

REFERENCES

1. CEPI, 2011.CEPI Annual Statistics.Confederation of European Paper Industries, Brussels, Belgium..
2. European Commission (1994) Council Directive of 20 December 1994 on packaging and packaging waste, 94/62/EC, Official Journal of the European Communities L365, 31.12.1994.
3. Miranda, R., M. C. Monte, A. Blanco. 2011. “Impact of increased collection rates and the use of commingled collection systems on the quality of recovered paper. Part 1: Increased collection rates”. Waste Management 31, 2208-2216.
4. Miranda, R., M.C. Monte, A. Blanco. 2013. “Analysis of the quality of the recovered paper from commingled collection systems". Resources, Conservation and Recycling, 72: 60-66.
5. ISO 536:2012. Paper and board. Determination of grammage
6. ISO 5636-5:2013. Paper and board. Determination of air permeance (medium range). Part 5: Gurley method
7. ISO 9895: 2008. Paper and board. Compressive strength. Short-span test
8. ISO 1974:2012. Paper. Determination of tearing resistance. Elmendorf method
9. ISO 2759: 2003. Board. Determination of bursting strength