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THE EFFECT OF THE VIRGIN FIBERS TO THE PROPERTIES OF DIFFERENT PAPER PRODUCTS

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Abstract: *The products from paper are widely used materials with several benefits. The corrugated paper keeps items protected through long-distance logistic processes and constant shipping and handling. The corrugated boxboards are ideal options for any industry's shipping, packaging and storage needs. Papers and cardboards are quite low cost and also provide environmental-friendly solutions, using recyclable materials such as used corrugated cartons and old newspapers.*
Recycling offers a reduction in environmental impact in densely populated regions and a large production of paper and board products. Generally, the use of recycled fiber produces paper with poorer mechanical properties due to the decrease in the interfiber bonding. The recycled pulp must be treated to restore its bonding strength, for which there are six methods possible: mechanical treatment, chemical additives, chemical treatment, fractionation, papermaking process modification and blending with virgin fiber. Although some mills produce 100% recycled paper, the majority augment their used pulp with some virgin fiber. Paper properties can be tailored within some ranges by modifying the properties of fibers, but the influence of fine quality on structure, strength and optical properties of paper can be even greater.
The properties of papers are essentially determined by their raw materials. Most of these raw materials are made from 100% recycled fiber, but as the quality of the waste fiber varies, different chemicals must be used to provide the desired or expected properties. From an environmental and economic point of view, the use of primary fibers can be an alternative.

Key words: virgin fiber, specific volume, tensile force, tensile strength, tearing strength

1. INTRODUCTION

Recycling has emerged as one of several possible solutions for environmental protection, and this includes waste papers, which can be collected and treated for reuse. However, a key issue for waste paper reprocessing is to preserve the optical and physical properties in the reprocessed waste paper fibers. It has been reported that sodium hydroxide (NaOH), a conventional deinking agent, turns the reprocessed paper yellow, and reduces strength of the reprocessed paper sufficiently thus an additional treatment is necessary (Zeyer et al, 1994).
The characteristic of the paper can be customized within some ranges by changing the properties of fibers, but the effect of particles quality on structure, strength and optical properties of paper can be even higher. Fibrillary particles improve bonding between fibers, and thus also tensile index of paper, while flake-like particles promote a light-scattering coefficient of paper. In the texture of paper, the fines fragments may act as small fibers, fill space between fibers, block fiber-fiber bonding, help in assembling fiber-fiber bonds, or simple stand on free fiber surfaces (De Silveira et al, 1996; Karnis et al, 1996; Peel, 1999). Fibrillary mechanical pulp particles are shown to gain strength properties, while flake-like elements are positive for the light-scattering coefficient of paper when mixed into a fines-free mechanical pulp with virgin fibers (De Silveira et al, 1996; Luukko, 1999).
Cellulosic fibers are negatively charged due to the presence of acidic groups (carboxyl, sulfonic acid, phenolic or hydroxyl groups), which either originate from cell wall constituents or being introduced during pulping or bleaching of fibers. Filler retention by a direct route affects optical characteristics of paper like brightness, whiteness, specific-scattering coefficient, which in turn directly influence printing characteristics (Tyagi et al, 2010). A paper-based product in most cases contains 90–99% cellulose fibers, which are the main structural part and the most important integrant influencing the final properties. A network of self-bonding cellulose fibers within network structure affects chemical and physical characteristics of the paper products. However, the chemical structure of cellulose is now well established and consists of β-anhydroglucose units with dominant hydroxyl groups, which are appropriate

groups for reactions. These are mainly due to the one primary and two secondary hydroxyl groups in each monomer unit in polymer structure (Fengel and Wegener, 1984; Sjostrom, 1994). Because paper network is composed from randomly laid fibrous (cellulose) and non-fibrous (fillers) materials, it contains a complicated set of cavity pore channels with a variety of capillary dimensions. Hence, it is readily permeable to liquids. However, the structure of paper can be modified during the contact of liquids because it disrupts hydrogen bonds, relaxes fibers, and produces dimensional modifications in pores and capillaries.

Binders or adhesives are among several matters generally added to the pulp slurry before paper sheet formation. Binders belong to the class of macromolecular substances. For example, high molecular weight compounds are mostly hydrophilic colloid parts. The main point of the binder adding is to improve the strength of paper products. However, other paper properties may be affected by binder addition. Other additives used in papermaking are fillers, sizing agents, etc.

2. EXPERIMENTAL WORK

2.1 Materials and methods

Tests were conducted with unbleached sulphite pine cellulose and recycled corrugated board. The materials were disintegrated with laboratory pulp mixer with water. Using these two types of suspensions, we prepared different mixed-pulps according to the ratio of cellulose and corrugated waste papers. Based on the dry matter content of the raw materials it was calculated the proportion of fibrous materials and the required mass values. To study the mechanical and physical properties of the mixed pulps, we produced sample-paper sheets using laboratory Erntst Haage sheet former.

2.1.1 Disintegration with laboratory pulp mixer

We disintegrated separate the cellulose and the paper waste in the laboratory pulp mixer. The glass jar of it is 10 l volume. The RPM of the mixer was 3000/ sec. We plucked the known weight waste paper into 3x3 cm pieces, then the material was soaked for 24 hours in 20 OC water. Then we disintegrated them for 20 minutes on 3000 RPM. We prepared the cellulose similarly to our method.

2.2 Sheet formation

The dry matter of the suspension in the mixer is known. Without the dilution we can calculate how much suspension we need for the sheet forming with 314 cm2 sheet size for a given grammage (basis weight). We produced sample-paper sheets with 80 g/m2 grammage using laboratory Erntst Haage sheet former. The sample sheets were stored in airtight plastic case until further examination.

2.3 Mechanical tests

To study the mechanical and physical properties of the different sample-paper sheets we used the most important methods and standards, like the bursting test, the tearing test, the tensile test and the capillary rise test of paper.

2.3.1 The burst test of the sample-papers

The burst test is frequently used as a general guide to the strength of paper products, like sheets, solid board and corrugated board. Measures the pressure required to puncture a sheet of paper or paperboard as an indicator of its load carrying capacity under specific conditions (unit: kPa). Based on the measured values were calculated the following parameter. Burst index means the bursting strength in kilopascals, divided by the basis weight in g/m2. On the other hand the burst factor can be calculated with the bursting strength in gram per centimetre squire, divided by the basis weight in g/m2 (kPa.m2/g). The burst test was performed according to the ISO 2758:2001 standard using Mullen system burst tester.

2.3.2 Tear test of the sample-papers

The tear strength of paper means the resistance of a paper sheet to tearing force (in mN) that it is subjected to. It is another important basic physical property of paper and paperboard. Also known as the Elmendorf test, the tearing test has been performed in the paper industry for many decades in order to measure the mean internal resistance of cellulose or papers to the propagation of a deliberately initiated tear. Based on the measured values were calculated the tear index which means: tearing strength/grammage, quoted in mN.m2/g. The tear test was performed according to the ISO 1974:2012 standard using Elmendorf Tear Tester.

2.3.3 Tensile strength test of the sample-papers

The tensile strength is the maximum stress to break a strip of paper sheet. It is one of the most important basic physical properties of paper and paperboard. The strength, length and bonding of fiber, degree of fiber refining and the direction of the fiber are the main sources of the tensile strength of paper. It is also depends on the quality and quantity of fillers used. It is a significant factor for many applications as like printing, converter and packaging papers. The tensile strength test of paper sheet is like to the other materials test, but the method of expressing is different. It is calculated with the force per unit width and express as N/m. It is also important to measure the stretch at break value. Stretch at break is a ratio (in %) of the elongation of a test piece, over its initial length, at the moment when the maximum tensile force is reached during a tensile test.
Based on the measured values were calculated the tensile index which index is defined with tensile strength divided by basis weight and express as Nm/g.
The tensile test was performed according to the ISO 1924-1/3 standard using L&W Tensile Tester.

2.3.4. Capillary rise of the sample-papers

For unsized papers such as blotting papers and other papers having relatively high water absorbency the Klemm method for determining water absorbency is used. Test pieces are immersed to a set depth in water and the height of the water rise is measure after a set time.
The capillary rise test was performed according to the ISO 8787:1986 standard using Klemm Absorbency Tester.

3. RESULTS AND DISCUSSION

3.1 Unblended Paper Properties

The properties of the papers made from 100% sulphite pine pulp and 100% recycled paper are shown in Table 1. Compared to sulphite pine papers, the recycled papers have a lower mechanical property values and a lower apparent density because mechanical properties are indicative of the strength derived from factors such as fiber strength, fiber length, and bonding.
The apparent density is a mediate scale of the elasticity of the pulp. Apparent density is simply calculated from weight, area and thickness of paper sample. A resilient pulp has a higher apparent density as its fibers are more lightly compressed into the holes of the paper sheet. Recycled fibers are more inflexible and not so lightly compressible (Minot et al, 1993; Ellis and Sedlachek, 1993). The different is 19%. The capillary rise value of 100% sulphite pine paper is 12 mm lower than 100% recycled paper (old carton paper). The different is 37%, because the fluid transport in paper depends on the fiber types, the refining, and the other materials of the paper (filers, sizing materials), and the recycled papers contains lot of different other components. The reused papers also had a nether tensile strength and tensile index, burst index and tearing values due to some loss in the interfiber bonding (Alince et al, 2001) from wreckage of the polysaccharide macromolecules as an outcome of dehydration (Minor et al, 1993). The grade of fiber bonding in the paper sheet can be mediate measured by burst test. The 100% sulphite pine sheet have a 168% higher burst value than, the 100% old carton paper and sign lower bonding areas in their recycled papers (Rushdan, 2015).

Table 1: Mechanical and physical properties of papers

	100% recycled paper (old carton paper)	94% recyc/ 6% sulph.	88% recyc/ 12% sulph.	85% recyc/ 15% sulph.	100% sulphite pine paper
apparent density [g/cm3]	0.65	0.63	0.64	0.64	0.81
tensile strength [kN/m]	3.104	3.473	3.554	3.873	6.610
stretch [%]	2.07	1.72	1.66	1.72	1.62
tensile index [Nm/g]	30.18	34.08	35.66	39.11	68.51
bursting [lb/in^2]	18.60	23.7	25.4	30.1	49.8
bursting index	1.34	1.66	1.74	1.98	3.52
tearing force [mN]	649.91	760.28	738.69	744.58	668.39
capillary rise [mm]	24.0	24.5	25.5	28	12.0

3.1 Blended Paper Properties

The properties of the papers made from mixtures of the sulphite pine pulp and recycled papers are shown in Table 1. The paper properties were highly affected by the sulphite pine pulp incorporated, with the changes suspended on the extraordinary property, percentage of mixing and the type of recycled paper used. The sulphite pine pulp improved the structural and mechanical properties. The mix of 15 % sulphite paper produced the biggest changes in the structural and mechanical properties and the mix of 6 % the lowest changes.

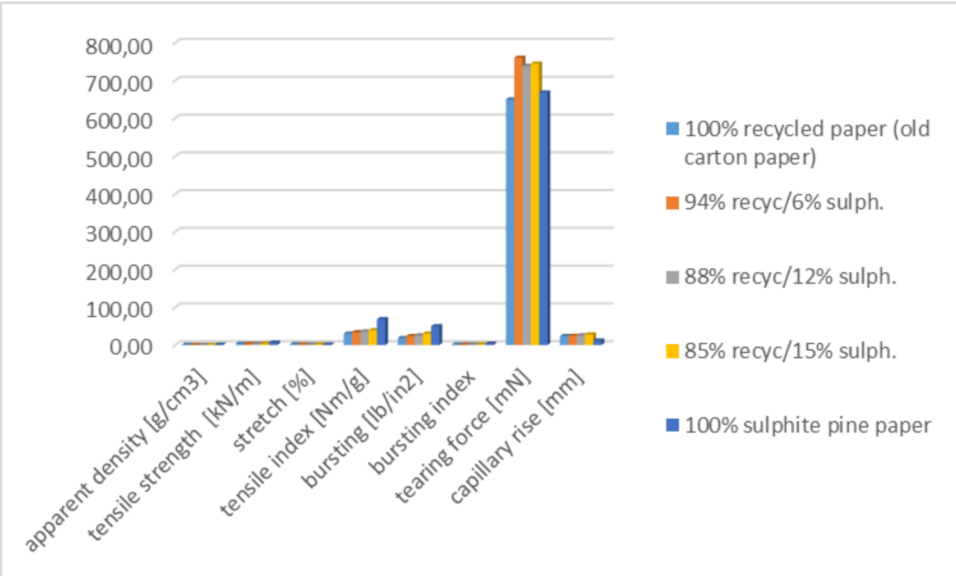

Figure 1: The properties of the papers

The addition of sulphite pine pulp increased the apparent density, tensile index, burst index of the recycled paper. Density is among the important structural properties of paper (Levlin, 1999). Structural properties deal with the placing of containing materials within the paper sheet (Peel, 1999). The results are explained the stability of a paper with randomly oriented fiber is impendent on the strength of the individual fibers and the stability and number of bonds between them (Kallmes and Perez, 1965; Page, 1969; Van Den Akker, 1958).

The strength properties of the blended recycled papers were not linearly related to those of the sulphite pine paper (Table 1 and Figure 1).

As it can be seen from the data, the value of the apparent density changed only in a little degree with the blending of the primer fiber. The increase of the tensile properties was in proportion to the degree of the added sulphite fiber, similarly to the tensile volume. The degree of the changes, that is the increase of the mechanical parameters can be analysed by the percentage of the fiber material correlation. See Table 2.

Table 2. The correlation between material composition and properties

properties	correlation
apparent density [g/cm3]	0.98
tensile strength [kN/m]	1
stretch [%]	-0.5
tensile index [Nm/g]	1
bursting [lb/in2]	0.97
bursting index	0.98
tearing force [mN]	-0.4
capillary rise [mm]	-0.7

4. CONCLUSION

The properties of recycled paper were affected by the addition of sulphite pine virgin pulp with high correlations. The changes on the properties diverse, impend on the particular property, percentage of blending. The blended recycled paper properties were not linearly related to the sulphite pine paper properties. The changes in the paper properties originate from the properties of the sulphite pine pulp - its elasticity, potential bonding area and other materials.

In conclusion, it can be said, that the sulphite fibers added to the recycled papers significantly increased the mechanical parameters of the product. Analysing the correlation values, it can be established there is very strong relationship between the volume of the mass of fiber and the measured properties. Except the capillary rise, whose correlation volume showed a weak relationship. The possible reason for this is that in the case of paper the water absorption and the capillary properties are dependent on the volume of added materials a larger degree than the strength and shape of the fibers and the number of bonds.

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