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Correlation between Dusting Gauge Method and Paper Quality Values

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ASIKAINEN, ELINA:
Correlation between Dusting Gauge Method and Paper Quality Values

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Paperi voi pölytä monella tavalla, mikä tekee pölyämistaipuvuuden mittaamisesta haastavaa. Yksi kehitetty menetelmä on Emersonin Dusting Gauge, jolla voidaan ottaa näytteitä paperista paperikoneella. Emersonin menetelmä ei anna standardia pölyn määrälle eikä rajoja tuloksille, vaan ne on jokaisen tehtaan määritettävä itse. Pölyämisen sanotaan usein johtuvan huonosta pintalujuudesta, mikä on seurausta partikkeleiden huonosta sitoutumisesta kuituverkkoon tai pintaliiman huonosta adheesiosta.

Opinnäytetyön tarkoituksena oli selvittää, onko pölyämismittausten tuloksilla korrelaatiota pintalujuuden, vetolujuuden, täyteainepitoisuuden, pintaliiman määrän, huokoisuuden ja pinnan karheuden kanssa.

Paperin täyteainepitoisuus vaikuttaa paperin pölyämiseen. Täyteaineen määrän lisäksi pölyämiseen vaikuttaa myös käytettyjen aineiden ominaisuudet, kuten partikkeleiden koko, muoto ja kemialliset ominaisuudet. Täyteaineiden sekä hienoaineksen sijoittumisella kuituverkkoon on merkitystä, ja tähän vaikutetaan paperikoneen viiraosalla. Paperin pölyämistaipuvuutta voidaan vähentää pintaliimauksella. Pintaliimaus sitoo täyteaineita ja hienoainesta kuituverkkoon. Myös muilla paperikoneen osioilla voi olla vaikutusta pölyämiseen, mutta suurimmat vaikutukset ovat viiraosalla ja pintaliimauksella.

Tämä on opinnäytetyön julkinen versio, jossa ei ole esitetty työn sisältämää luottamuksellista tietoa.

Avainsanat: paperin pölymittaukset, linting, pölyäminen

ABSTRACT

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Dusting of paper can be caused by different factors and can occur in many ways. This makes the measuring of the dusting tendency challenging. One method developed is Emerson’s Dusting Gauge, which can be used to take dusting samples of paper on a paper machine. Emerson´s method does not give standards for dust results. Those must be determined by the user. Dusting is said to be a result of poor surface strength which can be caused by poor bonding of particles on paper web or poor adhesion of surface size.

The purpose of this thesis was to find out whether the results of dust measurements have a correlation with surface strength, tensile strength, filler content, surface size amount, porosity and surface roughness.

The filler content of paper affects the dusting of paper. In addition to filler amount, the particle shape, size and chemical behaviour are factors that affect dusting. Distribution of fillers and fines in paper network is a factor affecting dusting and those can be affected on paper machine forming section. Dusting of paper can be reduced with surface sizing.

This is the public version of the thesis which does not include confidential material.

Key words: linting, dusting, dusting measurements

CONTENTS

1 INTRODUCTION

There are many types of paper dusting. The term dusting refers to a loose material on the surface of the paper, while linting refers to fiber or pigment particles. Material detached from paper accumulates to surface of rolls at printing press, leading to poor image quality and possibly a slowing down of production speed or interruption of production due to the need for cleaning.

Dusting can be a result of poor surface strength of the paper or poor adhesion of the surface size to the paper. Dusting tendency can also be affected by the amount of fillers and their distribution in the fiber network. The surface strength and other surface properties of the paper can be tested, but they do not directly indicate the dusting tendency.

Proper dusting testing would require a large-scale printing trials, but methods have been developed to test dusting tendency under laboratory conditions. One of these is Emerson’s Dusting gauge. This method allows dust samples to be taken on a paper machine.

The purpose of this thesis is to study the dusting tendency of paper by making dust measurements, and to find out whether these results have a correlation with the surface and tensile strength of paper and the surface and structural properties of paper.

2 TERVAKOSKI OY

The delfort group is a privately owned company and its headquarter is located at Austria. The company has six paper mills located in Austria, Hungary, Czech Republic, Finland and Vietnam, as well as nine converting mills around the world. Delfort employs 3,200 people. Delfort manufactures functional and specialty papers, such as packaging papers for fast food, thin papers for medical leaflets, catalogues and religious literature, cigarette and tipping papers, electrical insulating papers and various customized products. (Sustainability report 2020.)

Tervakoski Oy has been part of the delfort group since 2006. Tervakoski paper mill was founded in 1818. The mill is located at Tervakoski Janakkala. Tervakoski Oy is the oldest operating paper mill in Finland. Tervakoski Oy manufactures high-quality specialty papers tailored to customers' wishes.

Tervakoski Oy has fiver paper machines, supercalender and laminating line. Export rate is 95 % and Tervakoski exports go to more than 60 countries worldwide. Tervakoski Oy has 341 employees. (Delfort company presentation 2019.)

Tervakoski Oy produces ecopac papers, coated and uncoated thinprint papers, tipping base papers, electrical insulation papers & laminated products, design and hand-made papers. (Delfort company presentation 2019.)

3 UNCOATED FINE PAPERS

Uncoated fine papers include offset papers and lightweight papers. They are also called woodfree uncoated papers (WFU). Fibre raw material is chemical pulp, which can include both softwood and hardwood pulp. Filler content is from 5 % to 25 %. Basis weight of offset papers is from 40 g/m² up to 300 g/m². When talking about lightweight papers, basis weight is between 25 g/m² and 40 g/m². Offset and lightweight papers are often surface sized and slightly calendered. Important properties of these paper grades are surface strength and low linting tendency. (Haarla 2000, 35-37.) Other wanted properties are tensile strength, tear strength, stiffness, opacity, dimensional stability and brightness (KnowPap a).

TABLE 1. Most important properties of WFU paper grade.

Uncoated Woodfree Papers		
Runnability	**Printability**	**Image properties**
Strength properties	Ink absorption	Gloss
MD/CD tensile ratio	Surface strength	Smoothness
Stiffness	Curling tendency	Formation
Orientation profiles	Shrinkage	Opacity
Bulk	Residual strain	Brightness
CD profiles		
Moisture profile		

Fiber raw material composition of WFU papers is typically 20 % - 80 % softwood pulp and 20 % - 80 % hardwood pulp. Mainly used filler is calsium carbonate which gives good optical properties. (KnowPap a.) Often used filler and pigments for light weight papers are Ti02, zinc sulfide, PCC, calsined clay, amorphous silicate. (Laufmann 2013, 116.) Optical brighteners are used in products with high lightness. WFU papers should be hydrophobic to avoid wetting when getting in contact with water. Hydrophobicity is achieved by internal sizing with AKD or ASA. Amount of retention aids and additives is few precents. (Häggblom-Ahnger & Komulainen 2006, 67.)

4 OFFSET PRINTING

4.1 Principle

Offset printing is indirect printing technique. In offset, ink is first transferred from plate cylinder to blanket cylinder and then from blanked cylinder to paper in printing nips. Offset printing unit includes inking unit, dampening unit, plate cylinder, blanket cylinder and impression roller. Image and non-image areas of printing plate are on same level but have different surface energy. For that reason, image areas transfer ink and non-image areas transfer water to plate. Ink is then transferred from plate to blanket, and further to paper. (Hakola 2009, 55-61.) Principle of offset printing unit is seen in picture X. (KnowPap b.)

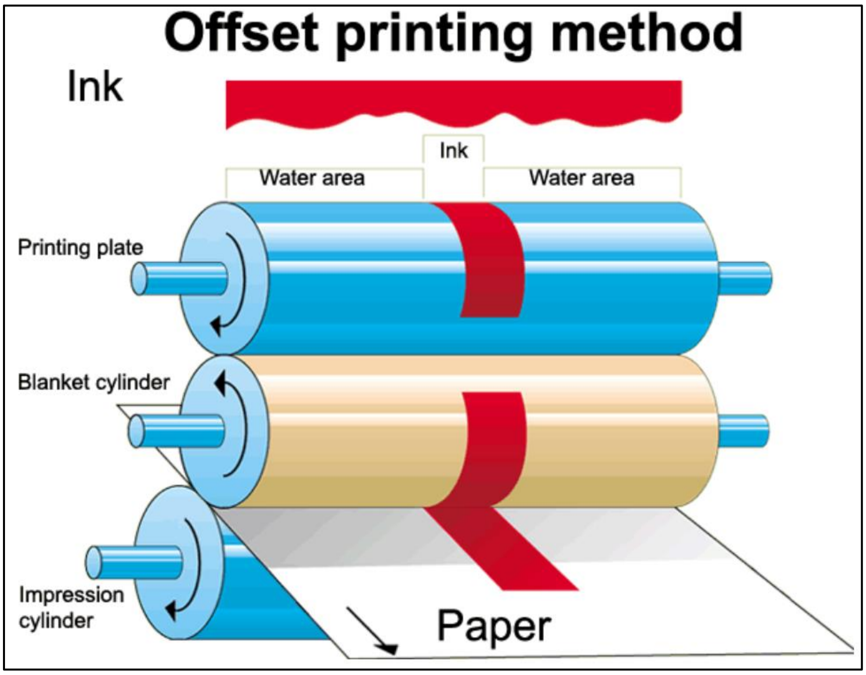

FIGURE 1. Offset printing unit. (KnowPap b.)

4.2 Linting and Dusting

Runnability of paper in printing is important for efficient printing process. Runnability problems such as web breaks can be caused by defects in paper web. To avoid web breaks paper should have good fracture toughness and good tensile strength. Other type of runnability problems are time dependent runnability problems. Example of those disturbances are dusting and linting. (Oittinen & Saarelma 2009, 111-112.)

When particles are loosed from paper surface it´s called linting or dusting. Linting is term for fibre or pigment particles released from papers and it occurs specially in offset printing of uncoated, non-surface-sized wood containing grades. Dusting is simiral phenomenon but means loose material on paper. (Oittinen & Saarelma 2009, 118.) Picking is quite similar phenomenon than linting. When particle that separates from paper is at least partly bonded phenomenon is called picking. Picking is usually caused by tacky inks and is related to poor surface strength. (Suontausta 1999, 198.)

Tacky ink can detach fibers from the paper in printing nip. When linting occurs at first printing unit it is usually caused by loose or poorly bonded material. Dampening water causes weakening of fibre bonds so loose fibers of fillers may detach from paper. In that case linting occurs at later printing units. (GATf Staff 1997, 100-102.)

5 FACTORS AFFECTING DUSTING PROPENSITY

5.1 Production Process

5.1.1 Refining

Fibers are main raw material of paper, and papermaking process is based on fibers ability to form bonds. Surface of fiber that is chemically separated is smooth, which makes its bonding ability low. Refining is an important part of papermaking process where fiber slurry is treated with mechanical force to increase bonding ability. (Häggblom-Ahnger & Komulainen 2006, 113.)

Primary effects of refining can be divided into six different mechanisms. External fibrillation improves inter-fiber bonding ability by peeling of fiber primary wall. Internal fibrillation cause swelling of fibers, surface area of fibers becomes larger and bonding ability increases. Straightening and curling of fibers are depending on refining consistency. Shortening of fibers improves formation but may cause decreasing of strength properties. Creation of fines improves creation of fibre bonds when fine particles fill voids between fiber network. Dissolution of fibre forms hemicellulose gel on fiber surface and increases bonding. (Häggblom-Ahnger & Komulainen 2006, 113-114.)

Refining process has a significant role in determining properties of paper. Refining of softwood pulp improves reinforcement properties of long fibers including surface properties. Hardwood pulp improves paper formation, optical properties and printability properties. Refining of short hardwood fibers decreases optical properties. (KnowPap c.)

Refining effects almost all properties of paper. With the amount of refining the type of refining has an influence. Refining can be more severe cutting or gentler fibrillating. Formation of paper is improved with more cutting of fibers. Improved bonding ability of fibers improves strength properties except tear strength. Paper surface roughness is reduced as effect of refining. (KnowPap d.)

5.1.2 Wire Section

Some of the paper properties that can be influenced at forming section are formation, bonding strength, MD/CD -tensile strength ratio and filler distribution. Wire section type has impact on filler distribution. In fourdrinier most part of fillers is in top surface due to one-sided drainage. On hybrid former water removal happens both ways so filler distribution is more symmetric meaning that there is less filler at surface of paper than in sheet center. On gap former filler distribution is dependent of furnish type. (KnowPap e.)

Forming section has the largest effect on fines distribution. High amount of fines at paper surface improves smoothness, bending stiffness and printability which makes good print quality and linting is low. (Niskanen & Pakarinen 2008, 35-36.)

5.1.3 Pressing

Main function of wet pressing is to remove water from the sheet. In addition to water removal wet pressing affect the properties of paper. Pressing affects to bonding of fibers and other compounds in two ways. Pressing brings fibers closer together which improves fiber bonding. Since bonds between fibers and fillers aren´t yet very strong the water flow from sheet to press fabric can move particles in the fiber network or out from the web. (Paulapuro 2008, 348.) Surface properties of paper such as roughness, and two-sidedness of paper can be affected with press felts and fabrics (Vappula, Tiilikka & Slater 2008, 416.)

5.1.4 Drying

Dryer section removes water from paper web by evaporation. Increasing the temperature in first part of drying section increases tensile strength, density and surface roughness. Drying of paper have effect on cross-direction and machine direction moisture profile. Drying can affect surface and strength properties. (KnowPap f.)

5.1.5 Surface Sizing

Surface sizing improves paper strength- and surface properties. For offset papers important benefits are improved surface strength, decreased linting, dusting and blistering. Surface sizing modifies paper surface structure and chemistry. To achieve end-use product requirement, it´s important that size is penetrated to sheet. Size penetration can be affected by properties of size and running parameters at sizer. Penetration is dependent of dry solids content and viscosity of size, and these properties need to be adjusted keeping the other in mind. Linear load and nip dwell time have effect on starch penetration. Effect of linear load on penetration is dependent of viscosity of size. (Paltakari & Lehtinen 2009, 310-313.)

Surface sizing is often done with starch. Sizing with starch binds loose fibers, pigments and other particles to paper surface and improves surface strength. That results as more even ink distribution and less dusting at printing. (Bruun 2009, 204.)

Starch for size is converted in specific conditions. Starch viscosity is dependent on cooking temperature and time. Small stage of converting provides too high viscosity product for coating or sizing use. High conversion of starch results as poor bond strength. (Maurer 2001, 35.)

5.1.6 Calandering

Main functions of calandering are adjusting thickness of paper, leveling caliper profile and improving surface properties of paper. Calandering improves printing properties of paper such as smoothness and gloss. (KnowPap g.)

Woodfree uncoated papers are often calandered with online hard nip or soft nip calender. Soft nip calander advantages are better control of two sidedness, better surface strength and higher surface smoothness. Pressure level in softnip calander is lower which cause less breaking of fibres. Higher temperature in softnip calander supports fibre bonding and reduces linting tendency. (Ehrola et. al. 2009. 69 – 75.)

In their study, Gerli, Eigenbrood, and Nurmi found that increasing the calender load did not affect the tensile and bonding strength of the paper but reduced the surface strength. At high filler load, effect of increased calender load on surface strength was significantly greater for paper with PCC as filler than paper containing GCC. (Gerli, Eigenbrood and Nurmi 2011.)

5.1.7 Winder

Dusting is one of quality parameters that can be affected at winder. Dust that is caused at winding is usually caused by dull edge of slitter blades. Basic dust removal improves air quality in working area and end-product quality. Devices remove dusty air from slitter area and replace it with clean air. (KnowPap h.)

There can be added additional device to winder that helps to produce dust-free end-product. Web cleaning system is placed between slitting section and rolling. Device is placed close to web surface and it removes the dust particles with high velocity air knife. To achieve good results both sides of the web should be equipped with dust removal heads. (KnowPap h.)

5.2 Raw Materials

5.2.1 Mineral Fillers and Pigments

Papermaking additives can be divided into three groups: mineral fillers and pigments (clay, talc, calcium carbonate, titanium oxide), functional chemicals (dry- and wet-strength chemicals, sizes, dyes) and process chemicals (fixative agents, retention aids, defoamers, biocides). Functional chemicals have effect on paper properties when process chemicals are used more to adjust process conditions. Division is not often this clear. Some chemicals used may affect the behavior of another, and thus, for example, process chemical can affect the quality of paper. (Alén 2007, 22-23.)

Fillers are used as raw material of paper to improve properties of product and to achieve economical production process. Fillers fill the space between fibers making paper smoother and improving papers printability and optical properties. Properties of fillers differ from fibers causing decrease in strength properties. Fillers don´t have same bonding ability and surface chemical properties than fibers. Poorly attached filler may cause linting later in production process or at printing machine. (Krogerus 2007, 56-57.)

Particle size and shape of filler and how they are situated in fibre network determines the influence on paper surface and strength properties. Fillers reduce sizing efficiency by adsorbing sizing agents and reacting chemically with components of sizing. (Krogerus 2007, 65-67.)

Main mineral fillers are calcium carbonates (GCC and PCC) and kaolin clays. Other mineral fillers used include talc, titanium dioxide and amorphous silicates. Kaolin clays can be divided into hydrous or calcined. Particles of hydrous kaolin have low aspect ratios and small surface area. Hydrous kaolin filler gives good optical benefits to paper such as high gloss and good printability. Particle shape of calcined kaolin gives higher opacity and brightness compared to hydrous kaolin. (McLain & Ingle 2009, 114-117.)

Natural calcium carbonate is found in three different form, chalk, limestone and marble. Coarse products may cause linting problems in printing. Fineness of GCC fillers is much greater than kaolin-based fillers which gives better resistance to dusting. (Laufmann 2013, 129.)

Precipitated calcium carbonate is fully synthetic product and can be used to improve paper quality by tailoring its form, size and shape. Different form and structure PCC used as filler are rosette-shaped, cubic-shaped and needle-shaped. Rosette-shaped PCC increases caliper and bulk comparing to kaolin or GCC but strength properties decrease. (Laufmann 2013, 130-132.)

Talc is hydrous magnesium silicate with lamella-type structure. Talc can be used as pitch control agent or as a filler to achieve specific printability properties. Softness and shape of talc have positive effect on surface properties. (McLain & Ingle 2009, 121.) Talc gives good gloss for SC gravure papers, but in SC offset papers talc has tendency to increase linting. Linting occurs due to hydrophobic talc particles and their lamellar structure. Linting propensity can be reduced by surface sizing with starch. (Krogerus 2007, 70.)

Titanium dioxide is often used as filler in thin print papers and in opaque grades. TiO_2 has high refractive index which gives excellent opacity. Disadvantages are its high price, high density and small particle size which leads to poor retention. To reduce costs TiO_2 is often used with extender, such as synthetic silicate or barium sulphate. (Laufmann 2013, 137.)

Amorphous silicates are specialty pigments used mainly in low basis weight grades. Adding small amount of pigment improves brightness, opacity and absorption properties. (Laufmann 2013, 138.)

5.2.2 Functional and Process Chemicals

Internal sizing

Sizing agents are functional chemicals that are added to the slush before headbox. Target of internal sizing can be to reduce liquid absorption with hydrophobic sizes or to increase dry or wet strength of paper with dry or wet strength agents. (KnowPap i.)

Hydrophobic sizing can be done with rosin sizes or with neutral sizes. The use of neutral sizing has become more common due to increased use of calcium carbonate as filler. Neutral sizing can be done with alkyl ketene dimer (AKD) or alkenyl succinic anhydride (ASA). In process that use PCC size reversion may occur when using AKD-sizing. AKD particles on PCC surface may react with water and sizing decreases. (KnowPap i.)

Dry strength agents work as binding agents. Mainly used is modified starch. Preparing starch for the process has great influence on how it will behave in process. Starch has an impact on retention and fines distribution and by that has great influence on paper quality. Starch effect on paper surface strength is shown in figure 2. (KnowPap i.)

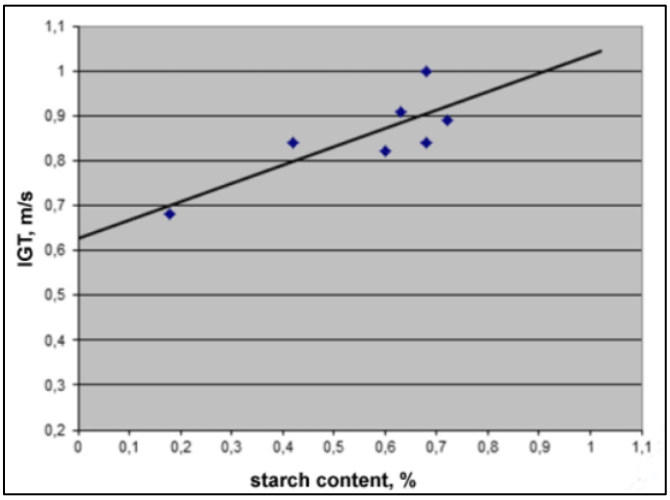

FIGURE 2. Effect of the wet end starch on the surface strength of paper (KnowPap i.)

Other dry strength agents are example vegetable glues, carboxymethyl cellulose (CMC) and synthetic strength additives. Adding of vegetable glue to pulp will increase strength properties and decreases porosity and linting. (KnowPap i.)

<u>Retention Aids</u>

Retention means proportion of solid material in paper stock (fibers, fines and fillers) that remains in paper web after wire section. Retention of fillers depends of filler size and density. Filler retention can happen mechanically as filler particles are trapped on paper web. Different kind of retention aids are used. (KnowPap j.)

5.3 PROPERTIES OF PAPER

5.3.1 Strength Properties

Tensile Strength

Tensile strength is the highest loading paper can resist before breaking. Unit of result is kN/m. Elongation is how much the test strip length increases before breaking. Tensile strength is measured in machine direction and cross machine direction and results indicates orientation of fibres. (Levlin 1999, 142-144.)
Refining of fibres improve bonding ability and good tensile strength is achieved with strong and bonded fibres. Strength of individual fiber determines the strength level. (KnowPap k.)

Surface Strength

Surface strength of paper indicates paper ability to resist individual fibers rising from paper. Surface strength is important property of offset papers due to tacky inks. Low surface strength may affect printing result and cause runnability problems such as linting and dusting. (Levlin 1999, 148-149.)

Surface strength depends on the bonding strength of paper surface and adhesion of coating layer. Surface detaching can be caused by fiber roughening. Wetting of fibers on paper surface due to dampening water causes swelling. Swelling makes fibre ends raise from paper surface and they are detached at printing nip. (KnowPap l.)

Surface strength of paper can be measured with IGT printability tester. Test is done by printing a test sample with standard oil at increasing speed. The force which damages the sample is directly proportional to printing speed and oil viscosity. After printing surface damage of sample is evaluated. Unit for surface strength value is cm/s which is the printing speed at the point where picking starts. (KnowPap l.)

5.3.2 Surface Properties

Roughness

Roughness of paper can be divided into optical roughness, micro roughness and macro roughness. Macro roughness is thickness variation caused by formation. Roughness can be measured by Bendtsen method. Method measures the flow rate of air that is forced through paper. Result of Bendtsen test is given in unit ml/min, the lower value meaning smoother surface. (Alava 2008, 94-98.)

Roughness can be affected by calendaring and distribution of fines and fillers. Fines and fillers in the surface layer of paper gives low roughness. Roughness can be reduced and increased at drying section. Smooth and hot drying cylinders evens the paper surface. Drying shrinkage increases roughness. (Alava 2008, 102-104.)

Porosity

As paper is composed from fibre network, the voids between fibers form a matrix of pores. Porosity of paper has great effect on durability of sizing and penetration of printing inks. (KnowPap m.)

Porosity of paper can be measured with air permeability tester. This type of porosity test is good at predicting the penetration of printing ink to paper as it indicates occurrence of larger pores. Methods for testing air permeability are Bendtsen and Gurley. Gurley method measures the time which it takes for specific volume of air to flow through paper. (KnowPap m.)

5.3.3 Basic Properties

Ash content

Ash content indicates the amount of fillers on paper. At laboratory ash content can be measured by burning a test sample in a specific temperature. Ash content is the ratio between burn residue and sample. Burn residue is inorganic material in the paper. Instead of ash content terms filler content or ash percentage are used as burn residue of paper is mainly filler. Measurement of ash content can be done as on-line measuring. (KnowPap n.) Increased filler content increases dusting of paper as surface strength is decreased (Lopes Velho 2003, 191).

Total filler amount

Total filler content can be measured with Ash Content Analyzer. The device can be used to determine the filler content, as well as the proportion of individual fillers, quickly and without destroying the sample. Another advantage of the traditional combustion method is that the combustion temperature of the various substances contained in the paper does not have to be taken into account. (Ash Content Analyzer.)

6 CONCLUSIONS

Dusting tendency of paper is often understood as poor surface strength, detachment of poorly bound particles or poorly adhered surface material from the paper. However, surface strength is by no means the only factor influencing dusting tendency. In addition to surface strength, other strength properties such as tensile and bonding strength have effect on it. Beside strength properties the structure of paper is an effecting factor. The paper must be porous enough for the surface size to adhere to it, and network of fibers and fillers must be dense enough that particles don´t detach from it.

Dusting tendency is affected with raw material composition of paper, and process conditions in different parts of manufacturing process. Like many other properties of paper, dusting can be significantly affected by refining. High refining level produces fibres that form strong bonds.

The filler content is said to increase dusting of paper, and some fillers more than others. Particle shape, size and chemical behaviour filler have effect on dusting. Surface sizing binds fillers, fines and pigments to paper surface and decreases linting.

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