Tampereen ammattikorkeakoulu

Measuring and Analysing White Top Mottling Phenomena

Ville Tamminen

BACHELOR'S THESIS
November 2022

Bioproduct and Process Technology

TIIVISTELMÄ

Tampereen ammattikorkeakoulu
Biotuote- ja prosessitekniikan koulutusohjelma

TAMMINEN, VILLE:
Ulkopakkauskartongin pinnan formaation mittaus

Opinnäytetyö 23 sivua
Marraskuu 2022

Nykypäivänä yhä useampi yritys haluaa panostaa ekologisuuteen, niin tuotannossa kuin lopputuotteen pakkaamisessakin. Tämän vuoksi on tärkeää, että kartonki- ja paperiteollisuus pystyvät vastaamaan asiakkaiden vaatimuksiin ja korkeisiin laatustandardeihin. Valmet Automation Oy on jo vuosien ajan kehittänyt uusia innovaatioita useille näiden tuotteiden valmistajille. Uutena tavoitteena olisi luoda mittausjärjestelmä korkealaatuiselle ulkopakkauskartongille, jonka pinnasta voitaisiin mitata white top mottling -ilmiötä. Tämä ilmiö johtuu kaksikerroskartongin ohuen vaaleasta kuidusta muodostuvan pintakerroksen formaation epätasaisuudesta, joka johtaa pohjakerroksen läpinäkymiseen.

Opinnäytetyön tarkoituksena oli selvittää, onko mahdollista luoda kuvatun kaltainen järjestelmä ja kuinka se parhaiten toimisi. Prosessia varten Valmet oli rakentanut prototyyppilaitteiston, joka sisälsi konenäkökameran sekä kolmea eriväristä valoa tuottavia LED-lamppuja.

Varsinainen työ suoritettiin vertaamalla nykyistä menetelmää, missä valmiista rullasta otettu näytepala analysoidaan laboratoriossa, sekä uutta mittalaitteistoa, jolla mittaus suoritetaan suoraan linjalta. Tutkimuksessa vertailukohtana käytettiin MottlingExpert-ohjelmaa, johon syötetään skannerilla otettuja kuvia näytteistä. Ohjelma antaa arvon mottlingin suuruudesta suoraan taulukkoon. Näitä tuloksia verrattiin kuviin, joita otettiin prototyyppilaitteistolla ja analysoitiin erityisellä MATLAB-skriptillä. Tuloksista ei saatu suoraan verrattavia, mutta vertailu onnistui soveltamalla.

Johtopäätöksenä voi todeta, että tulokset ovat kääntäen verrannollisia alkuperäisiin tuloksiin. Valojen väreillä ei näyttäisi olevan suurta merkitystä ainakaan korrelaation kannalta. Toki mittauksien määrää lisäämällä niitä olisi mahdollista saada.

Avainsanat: kartonki, formaatio, pakkaus, mottling

ABSTRACT

Tampereen ammattikorkeakoulu
Tampere University of Applied Sciences
Bioproduct and Process Engineering

TAMMINEN, VILLE:
Measuring and Analysing White Top Mottling Phenomena

Bachelor's thesis 23 pages
November 2022

Nowadays companies want to invest to be more ecological in production and packaging of the product. It is important that paperboard industry can respond to customers' demands. Valmet Automation Oy is developing a new measuring system for high quality packaging board. This system should be able to measure white top mottling phenomena. White top mottling occurs when the formation is bad on the top ply of the board, so the bottom ply can be seen through.

The aim of this thesis was to figure out if there is a possibility create this kind of a system and see how it would work the best. Valmet had built a prototype measuring setup that included a machine vision camera and led lamps that could produce three different colours of light.

The research itself was conducted by comparing the existing method to a new measuring unit that measures mottling on-line. The base measurements were taken from the program MottlingExpert. These results were then compared to the pictures taken with the prototype system and analysed by a specific MATLAB script. The results couldn't be compared directly, but some correlation could be found.

In conclusion, there were results and they were reverse correlation between them. The colours didn't have much variation.

Key words: paperboard, formation, packaging, mottling

CONTENTS

ABBREVIATIONS AND TERMS

CTP	Centre Technique du Papier
MATLAB	Programming and numeric computing platform
PTS	Papier Technische Stiftung
RGB	Red, green and blue colour model
STFI	Skogsindustrins Tekniska Forskningsinstitut

1 INTRODUCTION

This thesis work was made for company called Valmet Automation Oy. It is a Finnish automation firm that provides solutions and machinery for many different industrial sectors including paper and paperboard industry. Valmet has also long history in this field with earliest parts of the company starting to operate in the late 1750s.

The aim of this work is to find a solution to have on-line measuring unit for white top mottling for high quality paperboard. To achieve this, Valmet has worked earlier to make a prototype that can be used in this work. In the prototype measuring unit there are multiple different colour led lamps and one camera. Main goal in this thesis is to figure out which colours have the best ability to see white top mottling on the paperboard.

This thesis has theory part where paperboard making and quality standards are explained as well as what white top mottling is. Manufacturing process is very complicated thing so this work only will have the basics for the most part. In the methodology there will be more in-depth description of the prototype measuring device and details of how the measuring was done. And lastly some results and summary of the work.

2 PAPERBOARD

Paperboard is a thicker paper like product, that has some better attributes compared to paper including rigidity and foldability. While there is no clear-cut differentiation between paperboard and paper, ISO standards say that paper over 250 g/m2 grammage is considered paperboard. There are of course exceptions with multi-ply paperboard and such. (Robertson 2016, 175 – 177)

Because of its lightweight and strength, paperboard can easily be formed and cut. That's why it is mostly used in packaging. Different end-uses for paperboard include mostly magazines and paperback books, that require printing in high graphic quality. (Robertson 2016, 175 – 177)

2.1 Manufacturing process

The most used production process for paper making is forming wet web from raw material components and water. These two combines to make stock suspension that is laid on web. Water is used to distribute the raw material components evenly on the paper. This formed thin web then gets most of the water drained from it to make it stronger and to eliminate breaks. (Knowpap a.)

Rest of the water still in the paper web is then eliminated with vaporizing and pressing the web against the felt moving it through the machine. This is how the paper gets dry and is ready for other areas of the process. Finishing processes usually include coating and calendering. Paper making process and paperboard making process are similar, and mainly the differences are in basis weight and multi-layering of the paperboard. (Knowpap a.)

The most important component of paper and board raw materials are fibres, generally wood fibres. Since the properties of wood fibres in different pulp types vary to a great extent, then also the use of mechanical pulps, chemi-mechanical pulps, chemical pulps and recycled pulps is very much subject to change on different paper and paperboard grades. Other raw materials are fillers, adhesives, chemical additives and different coating agents. (Knowpap a.)

When coating the surface of paper or board - either one or both sides - a coating colour containing pigment (such as kaolin, talc or carbonate) and binding agent (such as starch or latex) is applied. The colour is applied to the paperboard surface more than will be needed. This guarantees that the coat weight can be corrected by removing the excess colour. After correcting the coat weight, it is dried. (Knowpap a.)

2.2 Quality

It's common to define quality in terms of the specifications that it meets, but perhaps it would be more accurate to speak of appropriateness. We should take into account whether the requirements that have been set for a system are appropriate as well as monitoring whether they can be met. (Knowpap b.)

The operations of planning, using, and maintaining are not independent. The process's best performance should be each person's main objective. The planning process should receive all available assistance for the planning outcomes to best meet the established needs. Plans must, if necessary, be adaptable to ongoing improvement. (Knowpap b.)

2.3 Environmental benefits

The most significant emissions to the atmosphere come from fuels, which can cause acidification in water courses and soil. The forest industry contributes 10% of Finland's sulphur and nitrogen oxide emissions. Sulphur emissions have been reduced by improving flue gas collection and treatment systems and tightening control over combustion plants. Reduced sulphur emissions have also resulted from the use of lower-sulphur fuels. Improved energy efficiency is being used to reduce nitrogen oxide emissions. Because of efficient recovery systems, particulate emissions are low. (Knowpap c.)

Global trends in the 2010s included rapid population expansion, even quicker middle-class growth, and increased usage of natural resources as living standards rose. Human activity on Earth have increased the amount of greenhouse

gases in the atmosphere, producing climatic warming and acidity of water systems, as well as waste creation, which has resulted in contamination in seas and other habitats. The scarcity of virginal natural resources is already causing uncertainty in raw material availability and price volatility in the manufacturing industry. (Knowpap c.)

As this type of development continues, critical natural resources will be depleted, and the fertile environment will deteriorate. To counteract these risks, humanity has improved its resource utilization, aiming to meet the requirements of consumers, businesses, and other players with fewer natural resources and energy. However, there is a limit to how much a current method, in this case the use of untapped natural resources, can be improved, and as that limit approaches, planning for a new, more systematic change in resource consumption has begun. (Knowpap c.)

Circular economy is one alternative for a replacement process. This means a form of operation that preserves the intrinsic value of raw materials and products by prolonging usage duration and utilization rate to the greatest extent possible. The value is preserved and circulated, therefore the name "circular economy." (Knowpap c.)

3 MOTTLING

3.1 Mottling in general

Mottling is one of the properties of paperboard and is usually a portrayal of the blotches on face of the paperboard and inconsistent patterns on the printed surface. Often referred as the print mottle is effect of the ink and the solvent not being properly absorbed by the paper. It can also be caused by inconsistencies in draining of the ink and the solvent. (Knowpap d.)

Mottling is often assessed as a visual composition that is very important property in the paperboard making process. If mottling isn't taken care of in the process, it can cause many problems in the end product, like unwanted differences in colour density of the paperboard. The formation of the base paper is important, because in case of it is nonoptimal, it can be directly linked to evenness of the coating layer. That can cause more problems in the form of printing mottle. Differences in coat weight can also be caused by the uneven formation of the paperboard. The conditions of the drying section can also then be affected, making the coating structure more uneven. This directly impacts the printed image being mottled and unwanted. Usually there are also more factors impacting mottling like pore size, pigment distribution and other surface properties. (Garcia 2018.)

The main components in causing mottling are formation and baseboard absorption being inconsistent. The coating also directly can affect the printing mottle forming. Since the coating consist mainly binders and mineral pigments, these can move and cause unwanted structures. This can cause variations in coat weight and the surface, impacting the ink absorption. (Garcia 2018.)

3.2 White top

Formation is key to having clean looking paperboard. If the formation is not optimal it can result in the surface having lumps. This phenomenon is particularly a problem for more heavier paper and paperboards. These lumps are usually coming from shrinkage from drying or unevenness of the distribution in mass density

in different layers. This includes flocks and voids in the sheet. In the drying, there can be different shrinkage forces applied to different parts of the sheets. This results in deformation. Also, if the layers are dried in different stages, the deformation can occur. (Kekko, P., Kiiskinen, H., Pakarinen, P. & Paltakari, J 2010, 280 – 286.)

Deformation in the drying of the different layers causes white top mottling. This means you can see the bottom layer of the board through the top layer. In unprinted board this is not good because there is no way to hide it. In high quality packaging white top mottling is very bad because of this. Uneven surfaces of the paperboard are often seen with naked eye. In case of white top mottling, you can see different shades of white on the paperboard. This can also result in printing mottle. (Kekko, P., Kiiskinen, H., Pakarinen, P. & Paltakari, J 2010, 280 – 286.)

4 MOTTLING MEASURING

There are many ways of analysing mottling and they can be categorized by the way of the analyse. Easiest, but not the most exact method is visual evaluation. In which a person doing the analyse uses only their eyes as evaluation tool. Other analyses often use some kind of a camera or scanner to input the image to a computer that does the analysis. These kinds of computed analyses are often rated on how good they correlate with the human eye.

4.1 Visual

Visual analysis of the paperboard is usually the first and easiest analysis, and it can be used almost anywhere. The main objective is to differentiate unsimilar parts of the board surface. Two main subjects of the analysis are contrast and size of the abnormalities on the surface. Contrast is defined as difference from the average intensity and size is the frequency of these abnormalities. In contrast there can be two different sides of the problem: are the spots lighter or darker than the average. Size differences can initiate the main cause of the problem with some being bigger and some smaller. (Wolin 2002.)

There is sometimes no particular reason to analyse samples with different methods to try and find the problems if human eye cannot detect anything. That means, that there are some ranges to what is acceptable and what isn’t. Also viewing distance can be a factor with visual analysis. Sometimes it can be more acceptable to have mottling in the sample if the product is not viewed so closely. But in high quality packaging, for example, this cannot be the case. Some people could have different perceptions of the absolute level of these measurements, so that is why visual analysis is not that accurate in some cases. (Wolin 2002.)

4.2 Laboratory

4.2.1 STFI

STFI as in Skogsindustrins Tekniska Forskningsinstitut develops STFI Mottling Expert, that is one mottling analysing tool uses a scanner to input samples to the program. They use advanced image analysis technique to filter the scanned images to simulate the human vision system. This ensures that the results are more reliable and correlate well with the visual analysis. To increase the reliability this method also uses reflectance calibration system in the scanning process. (Johansson, 1993.)

The conventional STFI model uses the MATLAB Fast Fourier Transform in one-dimensional power spectrum to get the standard deviation of reflectance. This is used to find a measure of print mottle. This type of model uses 1-8 millimetres wavelengths in band-pass image analysis. (Johansson, 1993.)

STFI method is one of the only available mottling tools that can reliably measure the white top mottling.

4.2.2 CTP

Centre Technique du Papier is France's Pulp and paper research and technical centre that has also made an effort to have its own mottling measuring tool. The i-Motto device has been designed to be as automated as possible and can hence be integrated as both a production control system and a paper development pilot tool. It is computer-controlled so that operating cycles can be programmed, including amount of ink to be used, homogenisation time, number of printing units simulated and backtrap time between each. (Centre Technique du Papier n.d.)

This model is mainly used to measure print mottle in offset printing. It can analyse ten centimetres by forty centimetres formats that simulate industrial printing. CTP's method is best used to analyse backtrap mottling for sheet and web printing. (Centre Technique du Papier n.d.)

4.2.3 PTS

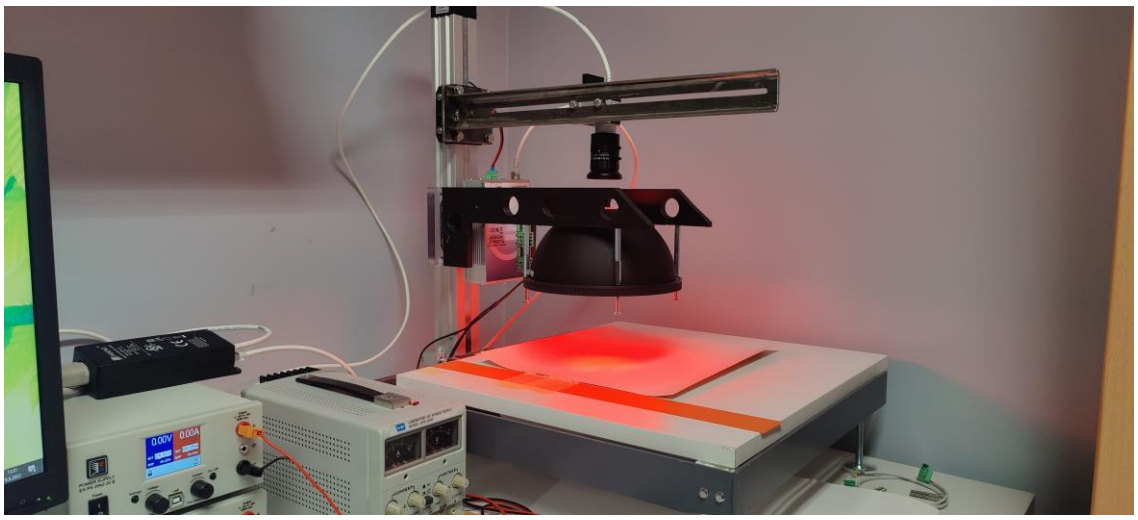
PTS DOMAS (Digital Optical Measurement and Analyst System) is German method developed by their research and service institute of German paper industry (Papier Technische Stiftung). It is a group of computer programs that you can use to analyse and measure different paper properties. (Papiertechnische Stiftung n.d.)

One of these modules has a mottling implementation that can be used to measure mainly printing mottle. Mostly this method is used by scanning the sample of backtrap mottle. (Papiertechnische Stiftung n.d.)

5 METHODOLOGY

The aim of this project is to develop and test a new kind of setup for measuring and analysing white top mottling on-line in the paperboard making process. Because this kind of equipment isn't widely used in the industry, the testing setup had to be made from the start. This time the testing setup was made ready by Valmet in their research and development laboratory.

The setup itself contains a machine vision camera (Basler acA1920-40gm) that can be used on-line also in the final rig. This camera can shoot 12-bit greyscale images that are suitable for analysing in two dimensions. With the camera in this setup there are three different RGB-LEDs that are set to show red, blue and green light as seen in the picture 1. These three colours can be combined to make many more. But in this test setup only these three were used. In picture 2 is a control unit for the LEDs, that can modify voltage input. Image area in this test was 867x867 pixels with 0,1 mm per pixel. This camera is also able to shoot forty-two frames per second.



PICTURE 1. Prototype measurement unit

The samples in this work were provided to Valmet by a Finnish paperboard mill. The samples were about forty times forty -centimetre pieces of different kinds of paperboard that they produce in this plant. There were four different white kraft linerboards from their line-up. These samples also had different grammages

ranging from 130 g/m^2 to 250 g/m^2. Within these samples there were always three of the same board that had different mottling values according to their own measurements.

PICTURE 2. Control unit for LEDs

The plant measured the samples with a program called MottlingExpert which is provided by STFI. This program only works in the laboratory as all the samples must be scanned to the computer for the analysis. MottlingExpert analyses samples with a MATLAB based script. The scrip uses a Fourier transform, that is a mathematical transform function. It is used to decompose functions that are depending on time or space into functions depending on temporal frequency or spatial frequency. What this means is the program transforms pictures into matrices depending on the darkness. This helps the program to analyse mottling spots that have different reflectance. The MottlingExpert has many different values for mottling, but usually the 1-18 mm mottling is measured and gives the best values for

comparing how good the samples are. This program was also used in this experiment to have some reliable base values and to see how the pictures taken with the camera correlate with results from MottlingExpert.

After having scanned all the samples with MottlingExpert, there were some samples selected for the camera testing, nine to be specific. With these nine samples the photos were taken with green, red, and blue colour with every sample. These pictures were taken by connecting the camera to the computer using an ethernet cable. With this connection you are able to see cameras view on the screen and record videos and photos using the camera's manufacturer's program, PylonView. PylonView also allows to control of the camera's settings, for example the exposure time which was the most important in this project. All the colours had to have basically the same grey colour in the photo to have better results with the MATLAB script. Exposure time used in these pictures differs a bit but is mainly between 4000 and 5000 microseconds. The photos were saved in 16-bit greyscale in BMP file format, also known as bitmap image file. This allows the script to transform the two-dimensional image to matrix and analyse it.

MATLAB scrip used here was an earlier experiment that had people from Valmet and Tampere University of Technology. The script was coded by one of the researchers from TUT and modified many times through the years. This script consists of many different codes that are used. It is quite a hard thing to read and understand if you don't have much experience with coding and MATLAB. But it basically puts out a table that has different values for mottling. These values were put into an Excel table and made into a graph for analysis.

6 RESULTS

As previously stated, the data was collected into a table that shows the mottling values of different coloured lights in different samples. These values are shown in the figure 1. In this table on the x-axis is presented the sample id that is the roll id and, on the y-axis, there is mottling value from the MATLAB script. These values are not the same as in MottlingExpert so they aren't directly comparable, though it can be seen to correlate in some capacity.

In figure 1 there can also be seen the variation of the different light colours, especially in the red light in comparison of the two others. The red coloured light has the longest wavelength, so it was assumed to have larger values. The only sample that the red one wasn't the biggest value is 60076305. There could be something different on the photo taken, because that is the only sample that doesn't behave like the others. Or the sample could have had different textures to have this outcome.

The second biggest values on the most samples are on the blue light, making the green the worst. Again, there are some differences on the same sample that didn't have red on the biggest value. Other than that, there definitely is at least some correlation with the different coloured lights.

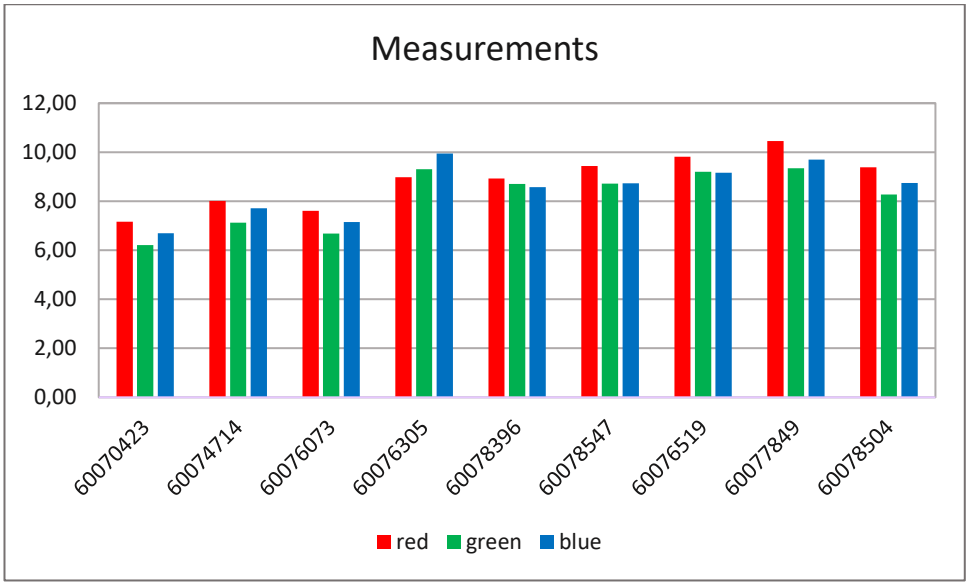


FIGURE 1. Measurements with prototype setup

Figure 2 shows the values of previously measured MottlingExpert values, and the new measurement conducted in this thesis. There is some variation, but mostly the values resemble the old values pretty good. The new measurements all have a bit higher value than the old ones, but that could be due to the samples being older or different scanning settings. All in all, they are pretty close to one another.

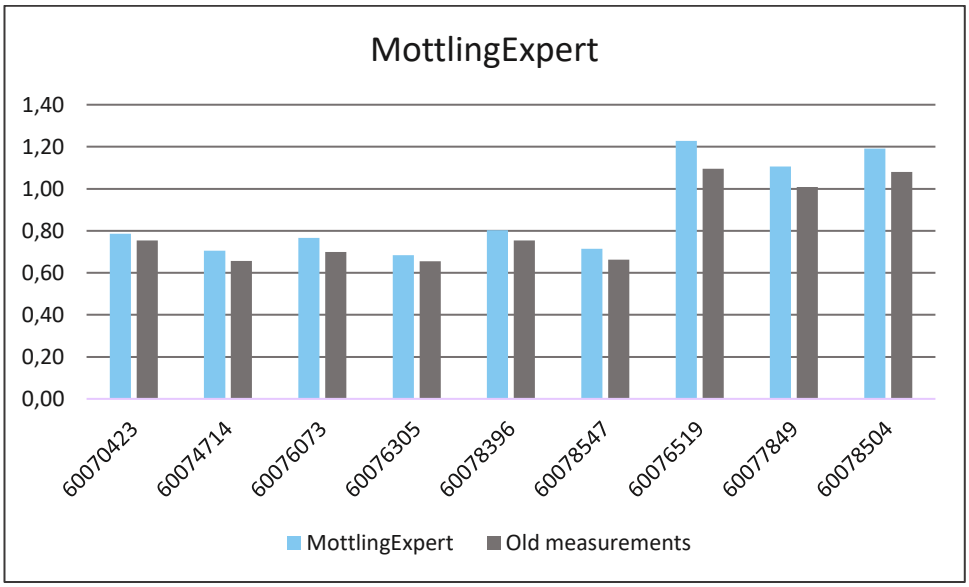


FIGURE 2. Measurements with MottlingExpert

Correlation between these two figures is difficult to analyse due to the measuring units being quite different. There can be seen some similarities though. Especially between the three samples (first three from the left). All these samples have values close to each other on both of the tables. Also, the two middle ones have bigger values than other samples in both. Other than that, it is very hard to say if there are some better samples or not.

In table 1 is a comparison of the different measurements including ones taken with the prototype setup and with MottlingExpert- program. Different colours in the table are there to differentiate the sample qualities. Same colour equals same brand of paperboard. These are in order according to their MottlingExpert values. There actually is some correlation when compared with the different colour options, in fact reverse correlation. All the measurements taken from the first brand are in line with each other. There are some that are not in order though. 60078504 is not correlating like the others, but there could be some other values that are

not right. For example, the lighting conditions weren't the same for this sample. There aren't many variations between colours.

TABLE 1. Comparison of the prototype setup and MottlingExpert

Roll number	Red	Green	Blue	MottlingExpert
60070423	7,16	6,22	6,70	0,79
60076073	7,61	6,68	7,14	0,77
60074714	8,01	7,13	7,72	0,71
60078396	8,93	8,70	8,58	0,80
60078547	9,44	8,72	8,73	0,71
60076305	8,98	9,30	9,94	0,68
60076519	9,82	9,20	9,16	1,23
60078504	9,38	8,27	8,75	1,19
60077849	10,46	9,35	9,69	1,11

In this first set of samples (coloured orange) that are rolls 60070423, 60076073 and 60074714, all the colours have same order in every sample. These samples are from 160 g/m^2 very good grade kraftliner that has been coated twice. Measurements from these samples have the least variation and can be comparable to MottlingExpert's values.

These grey samples are from the same kind of kraftliner as the samples in orange ones. Only difference being that grey samples have higher grammage in 180 g/m^2. In these samples red light doesn't correlate with MottlingExpert, but blue and green do.

Lastly the white samples are from uncoated high grammage kraftliner that doesn't have that high quality as previous two. As stated earlier these measurements are also not that in line with 60078504 sample being a little off. Other than that, the other values are correlating with MottlingExpert's values.

7 CONCLUSIONS

Many factors can be affecting quality of the paperboard, but with growing need for a high-quality packaging material, white top mottling must be accounted for. With more and more companies wanting to be more eco-friendly, paperboard standards and quality need to keep up. White top mottling is affected by poor formation on the top layer of paperboard; thus, the bottom layer can be seen through the top layer. This is almost always visible to the human eye, so companies want to eliminate it almost completely.

The prototype measuring tool for on-line measuring for white top mottling is not an easy task to achieve. There will be some obstacles on the way still, but at least some correlation was found with these tests. This can prove that this prototype can in fact be a possible task to develop even further. And maybe with some more time and effort put in it could be viable option compared to only using laboratory equipment. With more testing for the optimal conditions for this type of measuring unit can be found. There were also quite many problems with the MATLAB-script. So, if that could be fixed or testing with some similar software could be used, this can be the future of the white top mottling measuring.

REFERENCES

Centre Technique du Papier, I-Motto. N.d. Read on 14.11.2022. https://www.webctp.com/en/i-motto-mottling

Garcia, D., de Lima Luz Junior, F. & Vieira, O. 2018. Analysis of the Behavior of Mottling in Coated Board using Neural Networks. IJAERS. Read on 25.11.2022. https://ijaers.com/uploads/issue_files/22-IJAERS-APR-2018-42-Analysis.pdf

Johansson, P-Å. 1993. Print mottle evaluation by band-pass image analysis. Advances in Printing Science and Technology, 22, 403. Pentech Press.

Kekko, P., Kiiskinen, H., Pakarinen, P. & Paltakari, J. 2010. Drying and Paper Quality. In Karlsson, M. Papermaking science and technology. Book 9, Papermaking: part 2, Drying (2nd ed., totally updated version.). Helsinki: Fapet Oy. 280 – 286. Read 16.11.2022. Restricted access.

KnowPap a. 2022. v.23.0. AEL / Prowledge Oy. Paper and board production - general. Read on 16.11.2022. http://www.knowpap.com.libproxy.tuni.fi/extranet/english/paperboard_technology/general/frame.htm Restricted access.

KnowPap b. 2022. v.23.0. AEL / Prowledge Oy. Quality assurance of instrumentation. Read on 16.11.2022. http://www.knowpap.com.libproxy.tuni.fi/extranet/english/maintenance/2_systems/10_calibration/frame.htm?zoom_highlightsub=quality Restricted access.

KnowPap c. 2022. v.23.0. AEL / Prowledge Oy. Environmental impacts of air emissions. Read on 16.11.2022. http://www.knowpap.com.libproxy.tuni.fi/extranet/english/envir_contr/general/air_impacts/frame.htm Restricted access.

KnowPap d. 2022. v.23.0. AEL / Prowledge Oy. Effect of web structure on calenderability. Read on 15.10.2022. http://www.knowpap.com.libproxy.tuni.fi/extranet/english/paperboard_technology/12_calendering/3_effect_of_paper_composition_on_calendering/frame.htm Restricted access.

Papiertechnische Stiftung, Image analysis for the paper and printing industry (DOMAS). N.d. Read on 14.11.2022. https://www.ptspaper.de/en/industrielle-loesungen/products/image-analysis-for-the-paper-and-printing-industry-domas/

Robertson, G. L. 2016. Food packaging: principles and practice. CRC Press. 175 – 177

Wolin, D. 2002. Enhanced Mottle Measurement. IS&T's 2002 PICS Conference, 148 – 151.