FAST AND ACCURATE PRINT PREDICTION WITH OPTICAL METHOD

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Abstract

Faster and more accurate assessment of the printability of paper and board is now available in a new instrument that uses stereoscopic photography to analyze the topography of paper surface. This provides information about the presence of craters with different depths and fine surface variations that influence the quality of the print result. These two measurements (craters and surface deviation) help paper manufacturers produce paper that meet the end-customers' needs for quality printing.

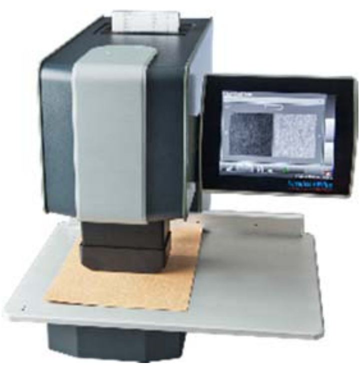

Figure 1 - L&W OptiTopo

Introduction

Requirements are constantly increasing for high print quality on packaging and printing grades of paper and board. Product differentiation, shelf appearance and branding drive the need for appealing and flawless graphics on the packaging grades.

The print quality is strongly related to the substrate surface properties.

For a good print result the ink must be released from the plate cylinder and transferred to the paper in a predictable way. Even small imperfections in the paper surface can cause poor ink transfer and have negative effect on the print result. Printing techniques like rotogravure, flexoprint and offset are especially sensitive to small scale variations and craters in paper surface. Typical print defects are *uncovered area* (UCA), *missing dots* and *mottling*.

Traditional air leak methods like PPS, Bendtsen, Bekk or Sheffield used to measure the surface roughness are often cost effective and have a rapid measurement cycle but does not reveal small scale variations and cannot find or classify craters. Effective area measured on each sample is typically 5 to 15mm^2

Other established topography methods are Stylus (a mechanical "needle" scanning the surface) and optical "stylus" using laser triangulation, however these methods do not have enough resolution to detect small scale surface variations or detecting and classifying craters.

More advanced topography measurement technologies like chromatic aberration, confocal laser microscopy (CLSM), atomic force microscopy (AFM), environmental scanning electron microscopy (ESEM) are all capable of measuring small scale surface variations and in some cases even classification of craters. These kind of instruments are typically very expensive, not user-friendly and not rapid enough to provide operator support in a production environment.

Stereoscopic imaging instruments that capture three-dimensional images of paper surfaces can be used to predict print quality by measuring small scale surface variations and classify craters down to the physical limitations of the camera and the optics at a micrometer scale. One such method is the OptiTopo developed and patented by Hansson & Johansson [1, 2]

The first instrument to utilize this method was *STFI OptiTopo* developed in 1999. Theory and use of OptiTopo method as a printability predictor has been described in earlier papers by Gustavo Gil Barros, Per-Åke Johansson and Carl-Magnus Fahlcrantz [3, 4, 5, 6].

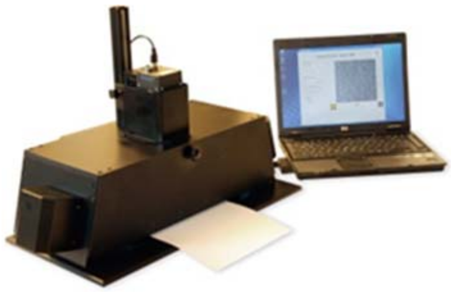

Figure 2 - STFI OptiTopo (3rd gen)

The *STFI OptiTopo* was in its first versions purely an experimental instrument but later, modified versions were sold to 3rd part customers, primarily other R&D facilities. This version of instrument (*STFI OptiTopo* 2nd and 3rd generation) had great flexibility in different settings for optics and geometry (measurement area, pixel resolution) and software (various analysis tools to filter out information from the measurements, however, it was not very user friendly and practical for everyday use in a paper laboratory. In 2015 a completely redesigned version of the instrument was introduced by ABB. Main focus for this new design was to make it user friendly and suited for daily use in a paper laboratory, providing clear and understandable numeric results that are relevant for print quality prediction without sacrificing performance, accuracy and repeatability from the *STFI OptiTopo*. The new *L&W OptiTopo* can be enhanced with additional software tools from Innventia, called *Expert OptiTopo* which target users in R&D and product development at paper mills.

Print methods used on paper substrate

There is a wide variety of technologies used for printing on paper. The main printing methods are:

- Offset lithography
- Flexography
- Gravure
- Digital printing: inkjet & xerography
- Screen printing

The trend is that printing promotional material is gradually migrating to digital printing while some packaging printing is moving to flexo [7].

Offset

In **offset lithography** a printing plate, which is most often made from aluminum, contains an image of the content that needs to be printed. When the plate is inked, only the image part holds ink. That inked image is subsequently transferred (or offset) from the plate to a rubber blanket and then to the printing surface. The method can be used to print on paper, cardboard, plastic or other materials, but these have to have a flat surface.

Offset is nowadays the most widely used printing technique for an extensive range of products such as books, newspapers, stationery, corrugated board, posters, etc.

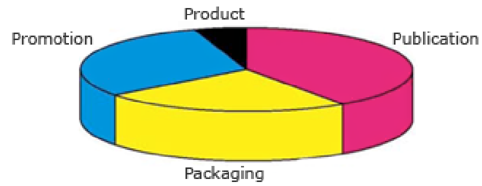

Figure 3 - Offset lithography per paper grades

Flexo

In **flexography** the content that needs to be printed is on a relief of a printing plate, which is made from rubber or other polymer. This plate is inked and the inked image is subsequently transferred to the printing surface. The method can be used to print on paper as well as plastics, metals, cellophane and other materials. Flexo is mainly used for packaging and labels and to a lesser extent also for newspapers where offset is taking market share. Flexo print quality is getting very close to gravure at a lower cost with recent development in printing machines, ink and substrate. Some packaging printing is moving from flexo to digital.

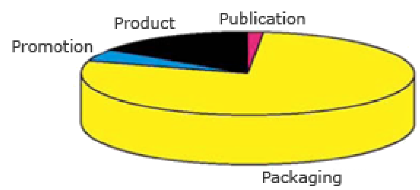

Figure 4 - Flexoprint per paper grades

Gravure

Gravure also known as rotogravure, is a technique in which an image is engraved into a metal printing cylinder. The cylinder is inked and the ink subsequently is transferred to the paper. Gravure gives a very high quality print result and is primarily used for high volume work such as newspapers, high print quality magazines (ex. Vogue Magazine), and premium packaging (ex. perfume boxes). Gravure is gradually losing market share to offset for publication printing and to flexo for packaging applications.

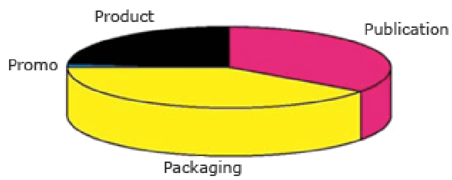

Figure 5 - Rotogravure per paper grades

Digital printing

Digital printing can be done in various ways. Two technologies dominate the industry:

- **Inkjet** – In an inkjet printer the image that needs to be printed is created by small droplets of ink that are propelled from the nozzles of one or more print heads. Inkjet is economical for short run publications such as photo books or small runs of books.
- **Xerography –** In xerographic printers, such as laser printers, the image that needs to be printed is formed by selectively applying a charge to a metal cylinder called a drum. The electrical charge is used to attract toner particles. These particles are transferred to the media that is being printed on. Laser printers are not only used in offices but also for small run printing of books, brochures and other types of document**.**

In 2009 both techniques jointly accounted for about 15% of the total volume of print. Digital printing is increasingly utilized for print jobs that were previously printed using offset, flexo or screen printing.

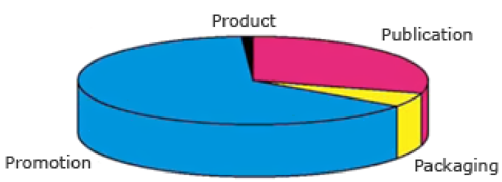

Figure 6 - Digital printing per paper grades

Screen printing

As its name implies, this printing technique relies on a screen, which is a woven piece of fabric. Certain areas of this mesh are coated with a non-permeable material. In the remaining open spaces ink can be pushed through the mesh onto a substrate. The advantage of screen printing is that the surface of the substrate does not have to be flat and that the ink can adhere to a wide range of materials, such as paper, textiles, glass, ceramics, wood, and metal.

Increasingly screen printing is being replaced by digital printing.

Importance of substrate topography for different print methods.

Most sensitive to small scale variations and micro craters in the paper are the printing methods rotogravure and flexo, both methods predominantly used in packaging grades. Poor ink transfer to substrate cause uncovered area (UCA), missing dots and mottling.

Uncovered area (UCA)

As the name suggests, UCA:s are areas which are supposed to be covered by ink but which are not. The cause for UCA:s can be that the paper does not accept the ink because of local variations in the surface topography. The area of UCA:s is generally found within the range 0.04-0.9 mm^2

The influence of the surface roughness on the occurrence of UCA:s has been studied on a more detailed level by Barros et al. [5]. These researchers characterized the surface profile on 14 commercial liner boards using the Opti-Topo technique. The acquired surface profile was frequency analyzed. The best relationship between the occurrences of UCA:s and the variance in surface profile was found within the wavelength ranges 0.125-0.25 mm, 0.25-0.50 mm and 0.5-1.0 mm. These wavelength ranges corresponds to typical equivalent diameters of the UCA:s

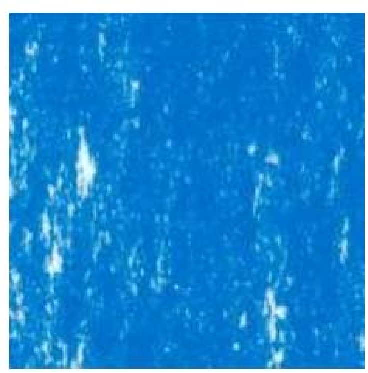

Figure 7 - Example of Uncovered Area defects

Missing Dots

When the printing roll passes over a crater in the paper it can cause a “missing dot” where the ink is not released from the print roll [9]. Depth of craters causing missing dots will vary between paper grades and printing methods, hence the measurement must be able to identify a range of crater depths.

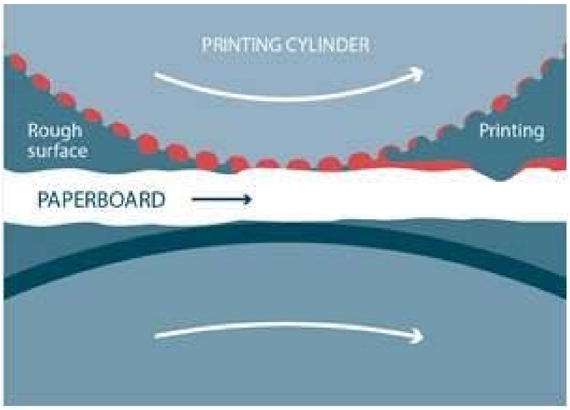

Figure 8 - Crater causing a missing dot

Figure 9 – Example of Missing Dots defects

Mottle

Mottle is a printing defect characterized by a spotty, non-uniform appearance in solid printed areas [8]. Different print characteristics have different types of mottle: there is a density mottle, a gloss mottle, or a color mottle, depending on what aspect is being affected. All forms of mottle are typically the result of non-uniform ink absorbency across the surface of the paper which can be caused by small scale variation in surface topography.

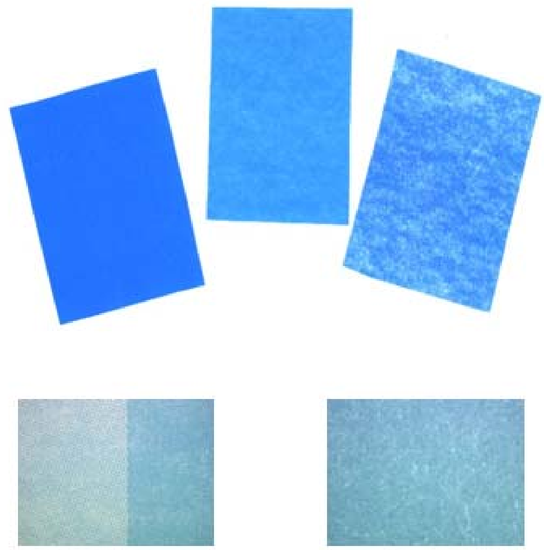

Figure 10 - - Examples of Mottling defects

Theory of stereoscopic imaging with the OptiTopo method

L&W OptiTopo is a non-contacting, optically based 3-D scanning instrument. The principle of the instrument is that, from variations between shadows and highlights induced on an object illuminated by a fully characterized light source (i.e. the position, direction and intensity of the illumination are known), it is possible to calculate the topography of that object. As an illustration, think of a sunset over sand dunes in a desert casting long shadows highlighting the topography of the landscape.

Figure 11 - Landscape with sand dunes in sunset (low angle light) highlights the topography

The instrument utilizes a high resolution CMOS camera, high precision optics and white light directed at the sample in a low angle [5, 6]. The lamps, camera and lens are mounted on a support that allows high precision alignment of all components and also blocking out exterior light to ensure reliable and repeatable measurements. Focus is automatically maintained independent of the sample thickness.

The measured surface with an area of ~1000mm^2 (32 x 32 mm) is captured with two photos where the sample is illuminated with low angle light, one picture with all light coming from right side and one with all light coming from left side. These two pictures are then combined and filtered to create a "gradient map", in the second step the gradient map is filtered to obtain the "height map" [1, 2] followed by a third filtering step to eliminate the influence of large scale variations in the image coming from wrinkles, buckling, waviness etc.

The measurement sequence takes 8-10 second for each sample

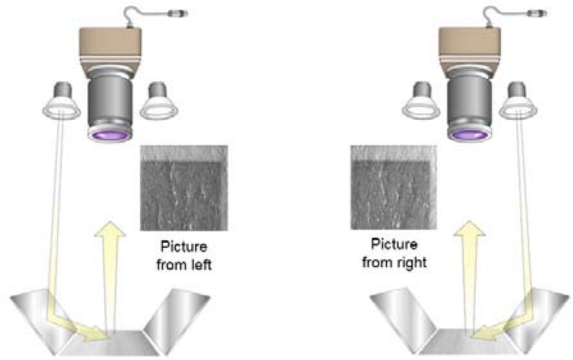

Figure 12 - Stereoscopic photography

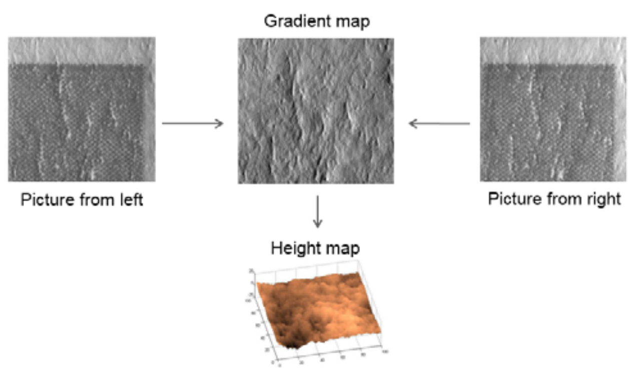

Figure 13 - Gradient map and Height map

OSD-value

An FFT-analysis is used on the height map to calculate the variations of height differences in different groups of wavelengths. The instrument is capable of separating 64 wavelength groups but for practical purposes in the standard version of the instrument this is filtered down to 10 groups in the range from 0,016 mm to 16 mm. In the "expert version" of instrument all 64 groups are available for analysis.

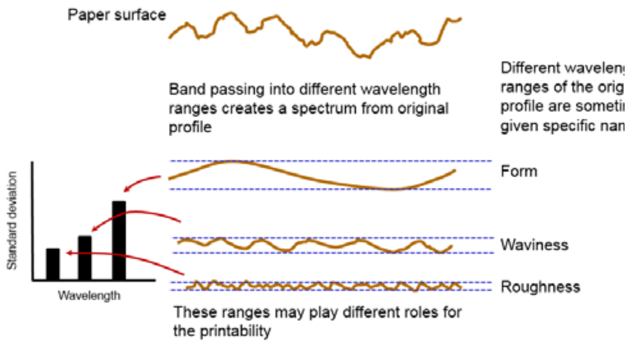

Figure 14- Mathematical characterization of surface

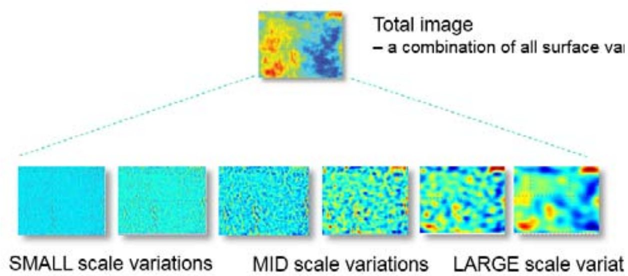

Figure 15- Result after 2 dimensional FFT analysis. Variations in topography are divided into small scale, mid-scale and large scale variations

Each wavelength group, is named sv1- sv10 and the instrument use group sv3-sv5 (small scale surface variations) to calculate OSD-value (OptiTopo Surface Deviation), which has shown best correlation to results from test prints.

Crater value

From the height map the instrument can identify craters in the paper surface. Different thresholds can be set to search for craters of various depths in the interval 0.3 µm to 10 µm. Every measurement can report the presence of three different crater depths, where the reported value is the percentage of measured surface containing craters deeper than the selected threshold.

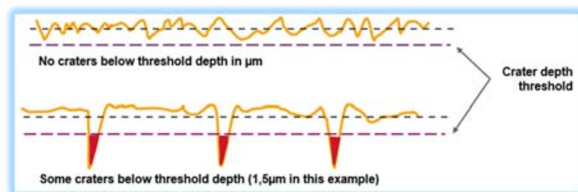

Figure 16 - Crater threshold 1.5um

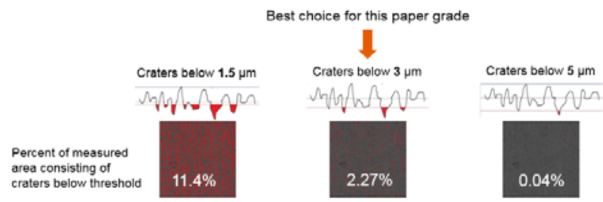

Figure 17 - Crater measurement on the same sample with three different thresholds

Crater value that is measured in the range of 1% to 10% has shown most relevance and correlation to print defects such as missing dots or uncovered area

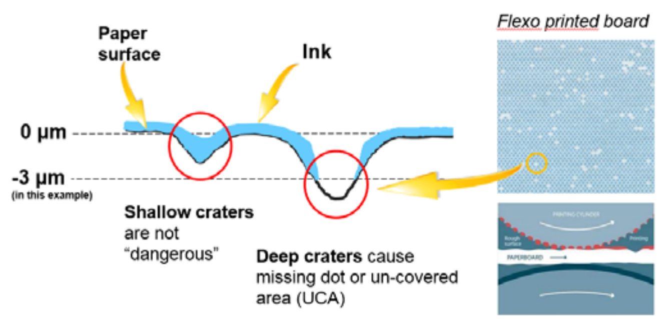

Figure 18- Craters below a certain depth can cause missing dots

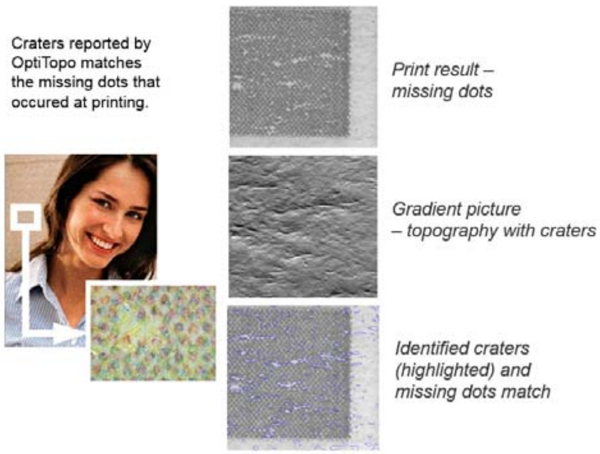

Figure 19 - Missing dots in test print matches the craters identified by OptiTopo

Earlier case studies

Innventia has over a period of 10 years provided a service to the global pulp and paper industry to measure paper samples with the OptiTopo method and compared results with test prints or simulations of print methods. More than 300 such case studies have been performed by Innventia. Following three examples comes from de-identified case studies made by Innventia.

Case study 1 – Missing Dots

In this case study a customer submitted 19 samples of double coated board. The print method that was used was full scale rotogravure and the test print was Cyan 25%. After the test print the missing dots were counted in a microscope. Samples were measured with the OptiTopo and PPS methods before the test print. In this test the OptiTopo method gave a relatively good prediction of missing dots where the PPS value did not correlate well.

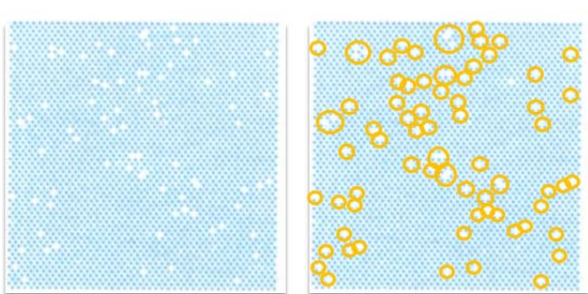

Figure 20 - Case study 1 - counting missing dots in microscope [10].

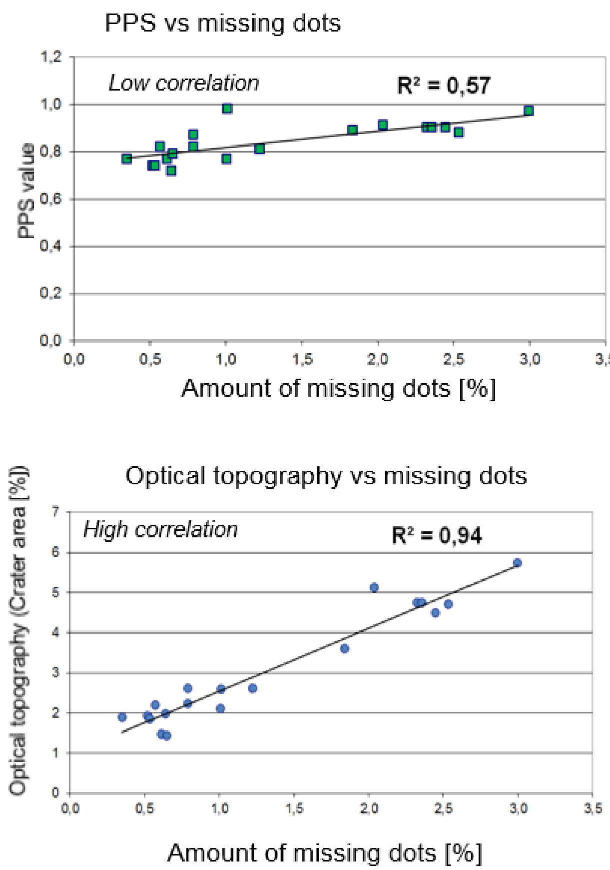

Figure 21 - Comparison between PPS and optical topography crater measurement versus missing dots [10]

Case study 2 – Improved top ply printability after machine rebuild

In this case study a customer experienced problems with Uncovered Area (UCA), mottling and wet-in-wet printing on a white-top liner grade. Printability problems were severe enough to justify a machine rebuild of the press section with the goal to improve paper surface properties for better print result. The customer was recommended by machine supplier to invest in a “reversed forming concept”, where the white-top side face a polished steel roll in a nip before leaving the press section. This is in effect a form of press section calendering which reduces the surface roughness in finished paper.

Innventia made a case study to verify print result and paper surface properties before and after machine rebuild. Test print were performed in a full scale flexo print and paper samples were tested with the OptiTopo and PPS methods (before and after machine rebuild). Test print after machine rebuild gave reduced print mottle, reduced UCA and improved wet-in-wet printing.

In this test the crater measurement with the OptiTopo method showed a significant reduction after machine rebuild. The -5µm craters were reduced by 85%, from 5.2% to 0.8% of total surface corresponding well with the much improved print result and also clearly visible smoother surface in gradient images captured by the OptiTopo method.
The PPS method could not identify this big improvement in surface structure (reduction less than 10%).

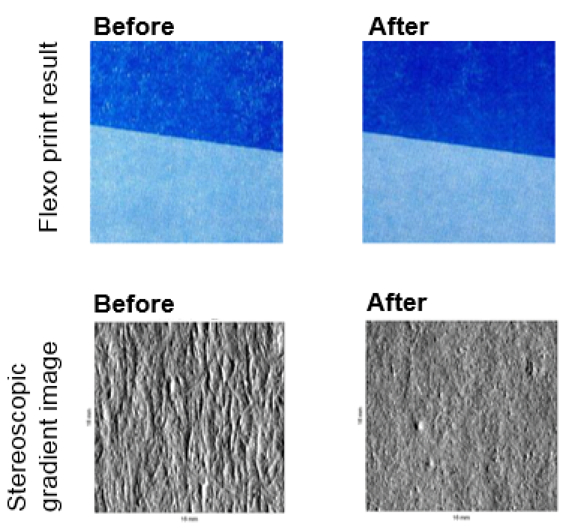

Figure 22 - Example of reduced mottling and UCA after machine rebuild. [10].

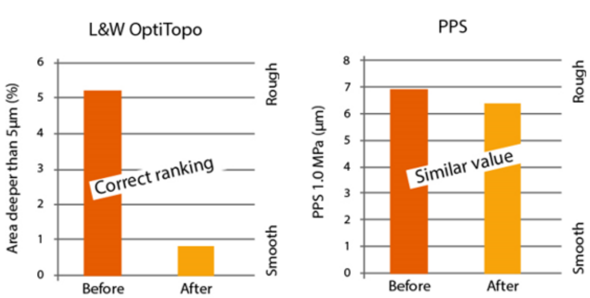

Figure 23 - PPS could not identify the improved surface wheras OptiTopo clearly measured a difference before and after [10]

Case study 3 – Predict mottling

In this case study a customer submitted 6 sets of samples of coated liquid board. The print method used was full scale flexoprint and test print was Cyan 100% (full tone). Mottle was measured with the instrument “Mottling Expert” [8] from Innventia.

Samples were measured with the OptiTopo (OSD value), Bendtsen and PPS methods in unprinted areas after the test print. In this test the OptiTopo method gave a relatively good prediction of mottle value where neither Bendtsen nor PPS value did not correlate well.

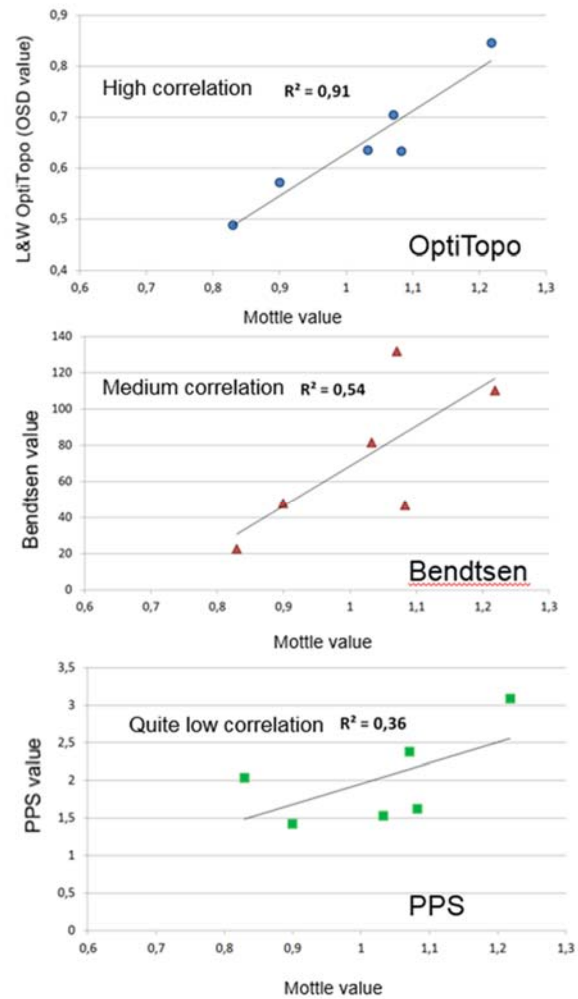

Figure 24 - Case study where OptiTopo proved to be better compared to air leak methods at predicting mottle value [10].

Conclusion

In today's world where paper producers and print shops are facing increased sensitivity for customer complaints and costly reclamations there is a clear need for a test method that can predict the print result better than the traditional air leak methods, yet be easy to use in everyday operation at an acceptable investment cost. The trend in the paper industry is increased production volumes of packaging grades with a demand for improved print quality where the dominating print technology is flexoprint. Measuring and classifying the paper surface properties for print quality prediction in a range where traditional methods cannot reach is now possible with optical topography using stereoscopic imaging technology, all packaged in a user-friendly test instrument designed for 24/7 operation by laboratory assistants or machine tenders.

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