Impact of Surface Topography on Print Quality in online Coated Folding Box Paperboard

Das A , Bhattacharya Abhijit

ABSTRACT

The topography of a coated paperboard surface has been found to have substantial impact on the print quality parameters; particularly due to uniform absorption and splitting of ink. The nanoscale nature of threedimensional surface undulations in coating layer structure is known as surface topography and its impact have been observed by macroscopic visual evalutation of print quality. This paper explores *firstly*, the impact of various Coating recipe and Infra Red Drying of Coated Folding Box board on the topography of coated board surface. And *secondly*, the impact of topography or the microscopic undulations of coated paperboard surface on print quality.

Keywords: Surface Topography, Infra Red Drying,

INTRODUCTION

Quantification and characterization of the coating Layer structure details are important for predicting the printing ink behavior on the paper surface during printing.

Characterization of Coating Layer Structure has been done by Hommelwerke Topography measuring device and it measures micro level undulations or roughness of the coating surface structure using a diamond probe tip, which moves with constant speed over the paper surface. Deflection of the probe tip produces a carrier frequency signal which is processed by an integrated computer and interpreted as surface roughness. Subsequently three dimensional micro roughness structure of coated paper surface is generated which is termed as surface topography.

Coating recipe made with different grade of pigment along with controlled and regulated Infra Red (IR) Drying of Coating Layer have been found to have great influence on the surface structure of online blade coated folding box board. Six different trial combinations using different coating recipe and IR drying combinations were conducted on Board Machine No: 4 at ITC LIMITED, in 300 g/m2 coated folding box board. Subsequently all these samples were evaluated for Surface Topography as briefed above.

For comprehensive evaluation of Print Quality of these trial samples and correlating the surface topography findings with print quality; a Six Color Offset Test Print Form has been specially designed to simulate conditions, promoting both Back Trap Mottle and Water Interference Mottle.

ITC LIMITED-PSPD
Unit: Bhadrachalam
Village: Sarapaka- 507 128
Dist. Khammam (A.P.)

Fair degree of correlation have been established between nanoscale nature of three dimensional surface undulations in coating layer and macroscopic visual assesment of print quality. Typically more uniform surface topography with narrow distribution of surface peaks and void structure have resulted in more uniform print appeal with minimum mottle tendency. This is attributed to more uniform absorption of oils present in the ink and subsequently uniform splitting of ink under the blanket in offset printing process.

Methodology:

A. Trials were designed using the technique of DOE-Design of Experiments. DOE is used to understand the impact of factors and interaction that impacts the output of a process. DOE helps to methodically build understanding and enhance the predictability of a process. The trial combination, derived from the DOE, was carried out on the Board Machine.
B. Six trials were conducted as per Design of Experiments, on 3 Ply Board Machine No 4 at ITC LIMITED. All these trials were conducted on ITC LIMITED Paperboards & Specialty Papers Division Unit: Bhadrachalam - 2 - online Blade Coated Folding Box Board 300 g/m2, with different Top Coat Recipe and IR dryer combination.
C. Surface structure of the Coating Layer have been analysed using Hommel T 8000 topography tester. Three dimensional topographic images and certain surface texture parameters like Spk – Surface Peaks, Sk and Svk – Surface Valleys analysis have been done for characterization of coating layer structure.
D. The different trial combinations were printed at the same time on a specially designed 6 – Color Offset Test Form in a commercial sheet-fed offset printing press.

The Test Print Form has been designed io simulate conditions, promoting both Back Trap Mottle and Water Interference Mottle within the same test sheet.

E. Visually assessing print quality and assign objective scoring by in house panel of experts.

The above methodology has been found particularly useful in establishing the correlation between firstly, different coating recipe with coating surface topography and secondly, coating topography with visual assessment of print quality.

Experiments:

1. Board Machine

Six trials were conducted on 3 Ply Board Machine No 4 at ITC LIMITED. All the trials were conducted on Coated Folding Box Board 300 g/m^2, with different Top Coat Recipe and IR dryer combination at the same speed (400 m/min) using the same furnish on the same day. The top coat weight was maintained at 12 g/m^2 for all the trials through Blade Coater with 9o bent blade ceramic tip blade. Gas IR dryer as well as Hot Air Dryers were used post coating for drying of Top Coat in all the trials. Three Hot Air Dryers were used for all the trials; however the number of Gas IR Dryers were regulated at different levels as part of the trial. For all these trials precoat recipe was same

and Coat Weight of 10 g/m2 was applied through Blade Coater at 4o bent blade ceramic tip blade. Other Board Machine process parameters like press load, draw and machine calendar loads were maintained at the same level for all the six trials.

Only two factors have been varied as per Design of Experiments for these trials. The factors are:

1. Top Coat Recipe – Two different coating recipes with different pigment combination have been used.

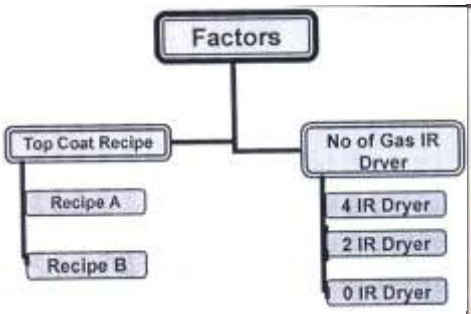


Figure 1: Depicts two factors and respective levels in each factor. Two different types of Coating Recipe with different pigment combination have been used. At the same time Number of Gas IR Dryers has been regulated at 3 Levels, i.e. Level1 - 4 IR Dryers have been switched on after the Top Coat Application. Similarly at Level2 – 2 IR Dryers and at Level3 – 0 No IR Dryer has been switched on after Top Coat application.

2. No of Gas IR Dryer – Three different levels of Gas IR Dryer (4, 2 and 0) have been used in combination with two different top coat.

Trial Combinations are as follows:

Trial 1 – Recipe A + 0 IR Dryer Switched on
Trial 2 – Recipe A + 2 IR Dryer Switched on
Trial 3 – Recipe A + 4 IR Dryer Switched on
Trial 4 – Recipe B + 0 IR Dryer Switched on
Trial 5 – Recipe B + 2 IR Dryer Switched on
Trial 6 – Recipe B + 4 IR Dryer Switched on

Under each trial combination 60 Metric Tons of material has been manufactured on Board Machine.

Subsequently surface topography analysis on these trial samples was carried out in-house on Hommelwerke Topography tester. At the same time print trials have been conducted by printing specially designed Test Form on commercial 6 Color Heidelberg SM 74 Sheetfed offset Printing Machine.

2. Topography Analysis

Three dimensional surface analysis of the coating structure of these trial samples have been evaluated on Hommelwerke Topography Tester. This device measures micro level undulations or roughness of the coating surface structure using a diamond probe tip, which moves with constant speed over the paper surface. Deflection of the probe tip according to the micro roughness structure of the surface produces a carrier frequency signal which is processed by an integrated computer and interpreted as surface roughness. Subsequently three dimensional micro roughness structure of coated paper surface is generated which is termed as surface topography.

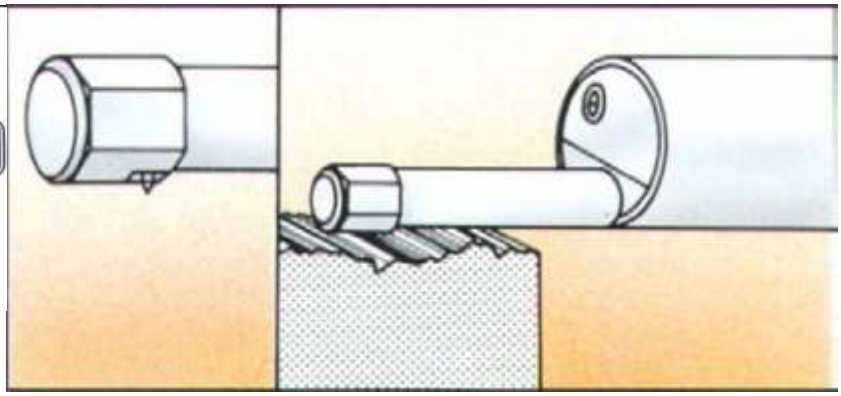


Figure 2: Above figure shows the diamond probe tip measuring the micro roughness of coated surface by virtue of deflection of the probe tip according to the micro roughness structure of the surface.

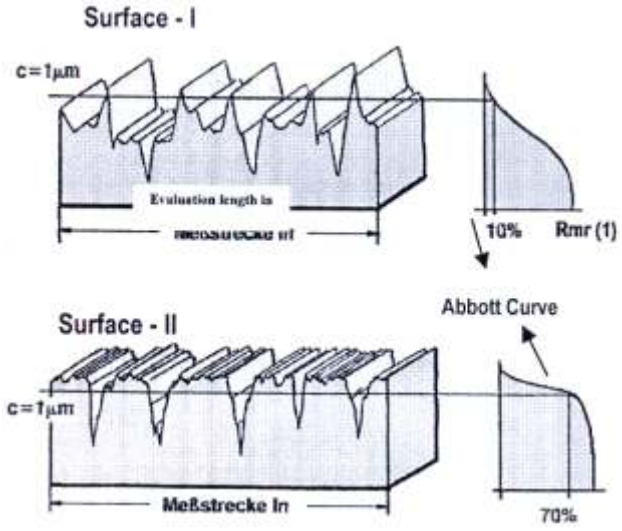


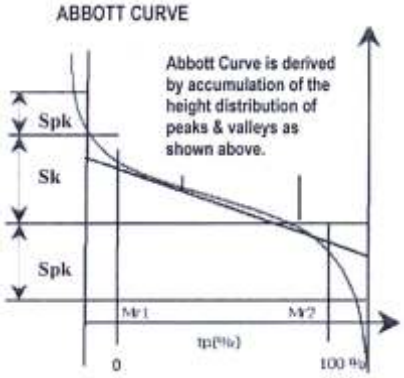
Figure 3: This figure demonstrates two different natures of surfaces. Surface – I consists typically more of peaks / hills and is more susceptible to wear when subjected to calendaring, rewinding or while printing. Thus non –uniform structure is more prone to non – uniform ink absorption while printing.

Characterization of the surface topography also includes measurement of surface texture parameters like Spk – Peak Region, Sk – Core Region and Svk – Void Region of the surface, These parameters are functional parameters for characterizing the surface texture, that is whether the surface is having more of peaks / hills or whether it is plateau shaped with the peaks are uniformly distributed or otherwise whether the surface is having more of valleys indicating more of voids with higher fluid retention properties. All these parameters (Spk, Sk and Svk) are defined from the surface bearing area ratio curve which is also called the Abbott curve, and is calculated by accumulation of the height distribution histogram of the surface peaks and valleys structure.

Whereas, Surface – II is typically plateau shaped having large number of void structure. This kind of a surface structure will have more fluid retention, which is more porous in nature.

Abbott curve for the above two surfaces as shown above will be totally different, since the peaks & valleys distribution is different for the two surface. For Surface – I, the slope of Abbott Curve is steaper whereas for Surface – II it is flat.

Various components of Abbott Curve is explained elaborately in the following section.



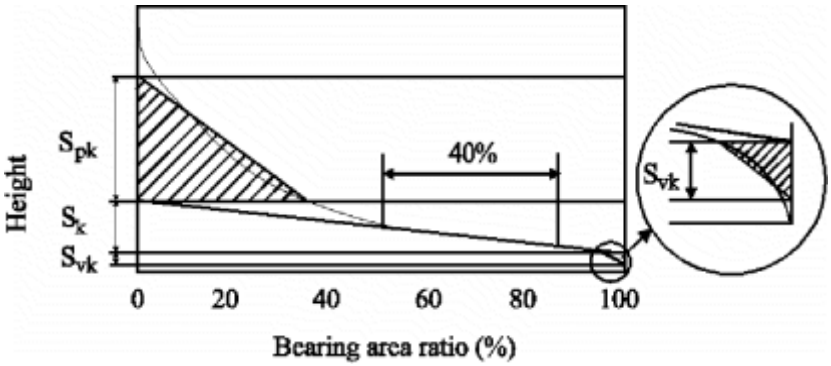
Spk: It is defined as the Reduced Peak Height and is a measurement of the peaks on the surface above a reference line. These peaks will be the areas of most rapid wear when the subjected to friction, while calendaring, rewinding or while printing. Higher the Spk value, higher is the non –uniformity on the surface and hence higher is the probability of non –uniform ink absorption while printing, thus leading to undesired print results.

Sk: It is defined as the core region and is the height difference between the intersection points of the found least mean square line. If the surface is more of a plateau shaped, Sk value will be higher, indicated flat surface with less of of peaks and valleys.

Svk: It is the valley depth on the surface and is a measurement of the void structure. Higher the value of Svk, higher is the depth of the valley or void indicating more prous structure.

These parameters are derived from the Abbott curve as folloes. First, the least mean squares line fitted to the 40% segment of the curve that results in the lowest decline, see figure below. Extend this line so that it cuts the vertical axes for 0% and 100% and draw horizontal lines at the intersection points. Then draw a straight line that starts at the intersection point between the bearing area ratio curve and the upper horizontal line, and end on the 0% axis, so that the area of this triangle is the same as the area between the

Hence, the functional parameters Spk – Peak Region,



horizontal line and the bearing area ratio curve. Using the same principle, draw a line between the lower horizontal line and the 100% axis.

Sk – Core Region and Svk – Valley Region is arrivedat and interpreted for characterizing surface topography. Results from above mentioned topography analysis are consolidated for predicting print performance of various trial combinations, which is discussed in the section "Results & Discussion".

3. Printing Trials

Print trials were conducted on commercial sheetfed offset 6 Color Heidelberg SM 74 Printing Machine.

All these trials were conducted on specially designed 6 – Color Test print form, which has been designed to evaluate both of the back trap mottle as well as water interference mottle within one single sheet. The was possible by printing Cyan in 1st, 3rd and 6th Unit simultaneously, thus enabling evaluation of Effect of Multiple Ink Splitting as well as Ink Repellence without any change in ink sequence.

However, since in most of the commercial jobs, color sequence is K C M Y (where cyan is printed after black & before Magenta) in this test print form Cyan is again printed in the 3rd station.

The color separation on the offset plates was done in such a manner that, same four color image & other test elements could be printed three times simultaneously, using three different 4 Color Sequences, which are:

- C K M Y – Cyan Printed in 1st station
- K C M Y – Cyan Printed in 3rd station
- K M Y C – Cyan Printed in 6th station

2000 sheets were printed under each trial combination in identical press settings on the same day using the same plate, blanket, packing material and ink & fountain solution. Before starting up the trial, Optical Density Profiling was done across the width of printing machine for all the colors individually. This was done in order to minimize interference of external factors on print quality like:

- Variation of Pressure between Plate, Blanket and Impression Cylinder
- Non – Uniformity of Ink and Fountain solution feeding Levels.

For all the trials SIEGWERK (Previously SICPA) sheetfed offset process color inks were used.

Machine make ready was done using 300 g/m2, 450 Micron thickness board (same as that of trial material).After completing the make ready all the trial combination were printed at a stretch, without stopping the press at a constant speed of 10000 sheets per hour. 2000 sheets were printed under each of the six trial combinations.

10 consecutive sheets form each of the trial combination were randomly selected for visual assessment of print quality.

Results & Discussion:

1. Hommel Topography Analysis Results

Samples pertaining to all the six trial combinations were subjected for

Color Sequence of Test Print Form

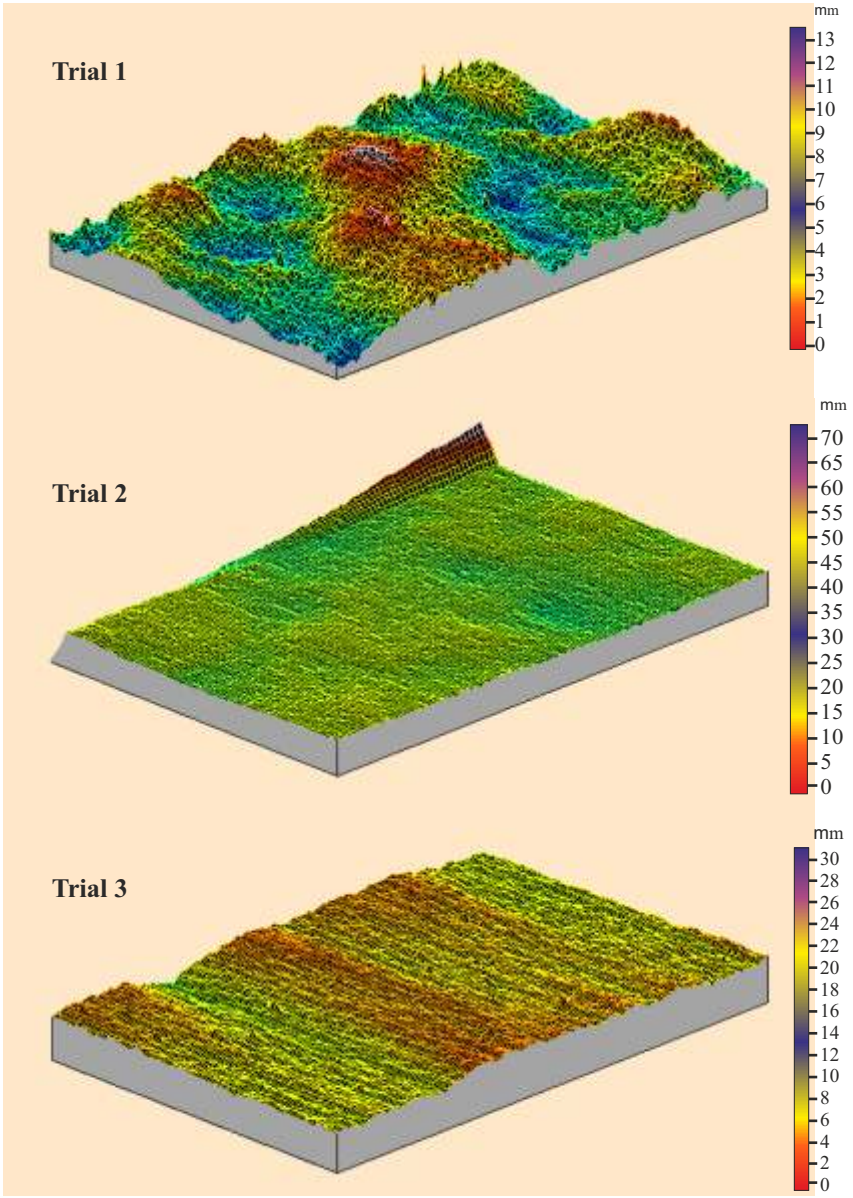
1	2	3	4	5	6
Cyan	Black	Cyan	Magenta	yellow	Cyan

Table 2: Cyan is printed in 1st Station to study the phenomenon of Back Trap (Both Dry & Wet Splitting). Multiple splitting of this ink under five subsequent printing nips, makes it highly susceptible to Back Trap Mottle.

Topography measurements on the Hommel Topography T8000 measurement devise.
Square samples of size of 5 mm X 5 mm have been used for topography evaluation.
Following are the three dimensional topographic image generated by the equipments for each of the six trial combinations.
The three dimensional topographic images are shown above for the paperboard surfaces made with combination od different coating and IR Dryers.

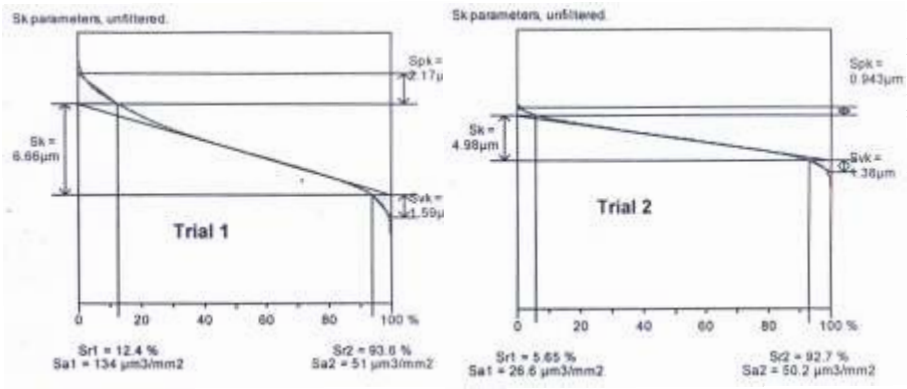
Similiary Abbott Curve and all other functionsl parameters (Spk, Sp, and Svk explained in the earlier section) have ben analyzed.
Following are the ABBOTT Curve for all the trial combination.

It is observed that different coating recipe in combination with regulated IR Drying has resulted in different Coating Structure. As it is seen that Coating Recipe A with 2 IR Dryers (i.e Trial 2) have resulted in very uniform structure with low peaks and valleys structure among all the trial combinations. Therefore it is expected that due to more uniform ink absorption and splitting in the offset print trials, trial combination 2 shall yield superior print quality. Similarly as the Topography and functional parameters are poor for Trial Combination 1 and Trial Combination 3, the print appeal is also expected to be poor due to non – uniform absorption & splitting of inks. Let us find out in the next section when we evaluate the Print Quality of all these trial samples.



The three dimensional topographic images are shown above for the paperboard surfaces made with combination od different coating and IR Dryers.

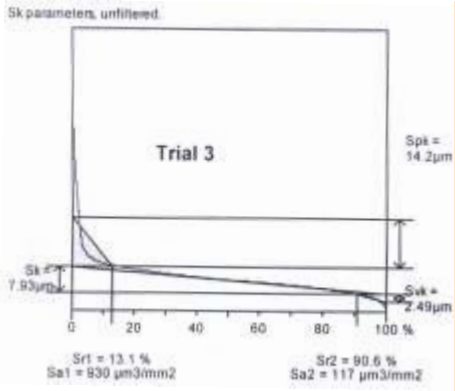
2. Print Quality Assessment

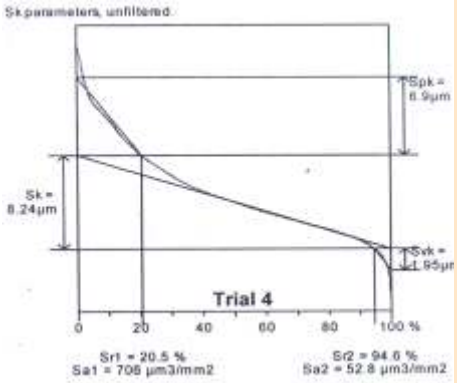


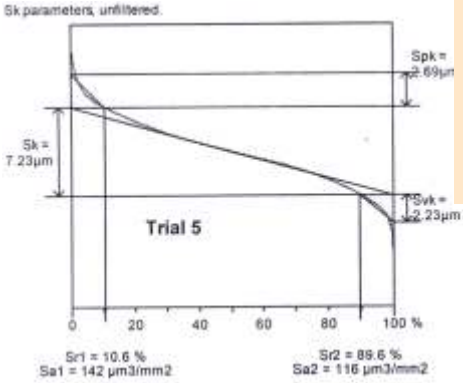
After conducting the print trials, visual rating was given on a scale of 1-5 by panel of appraisers comprising Appraiser A–A, A–J and A–S. The panel members have been selected based upon their expertise and experience.
Visual rating has been assigned to each of the printed samples by three appraisers on a scale of 1 – 5, where;

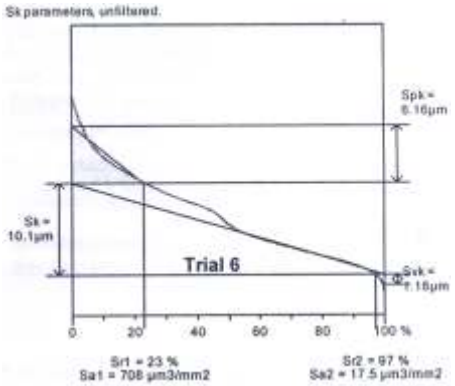
1: Very Good Print Quality
2: Good
3: Moderate
4: Bad
5: Vary Bad Print Quality

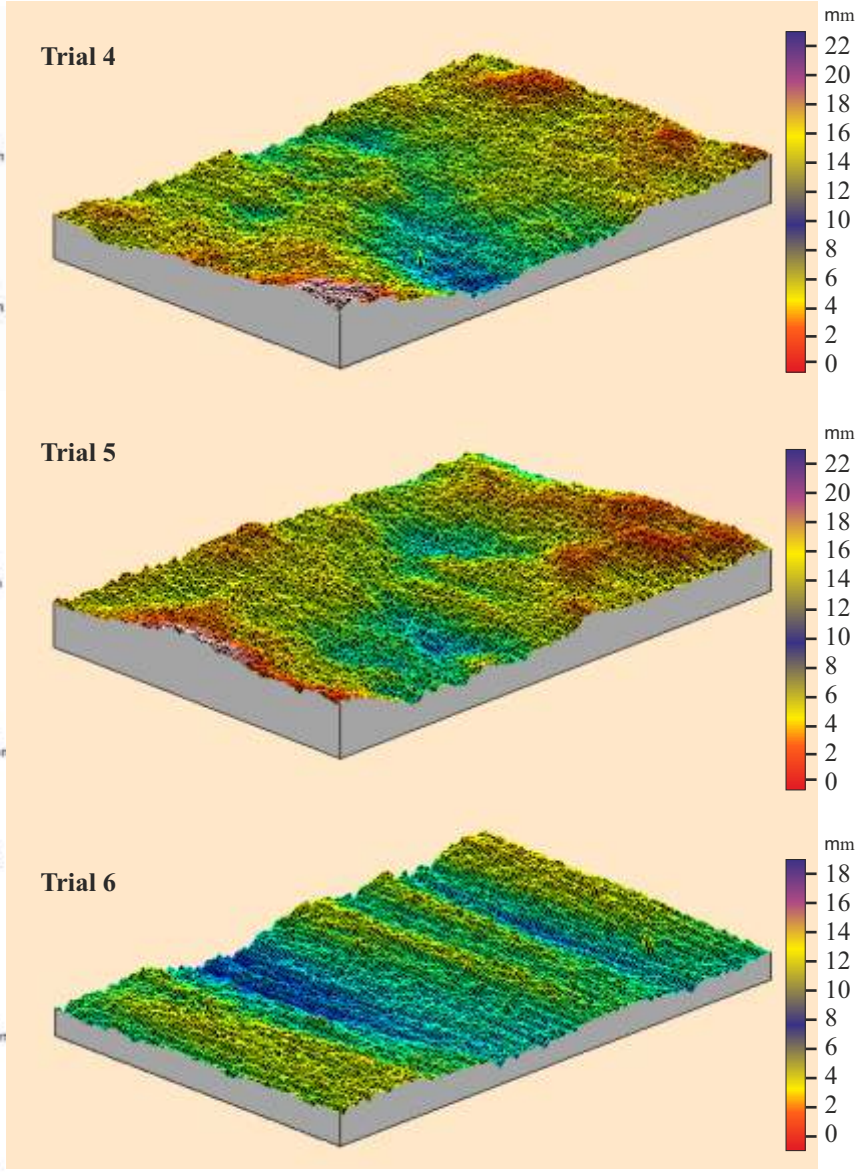
However, instead of assigning one score to the entire printed sheet, it was has been divided in four region of











As seen above, Trial Combination 2 (i.e made with Coating Recipe A with 2 IR Gas Dryer Combination) is demonstrating very uniform three dimensional surface structure.

Summary of Topography Analysis

Trial Combination	Spk - µm (Peak)	Sk - µm (Core)	Spk - µm (Core)	Remark
1	2.17	6.66	1.59	High Core
2	0.943	4.98	1.38	Low Peak and Valley
3	14.2	7.93	2.49	Very High Peak and Core
4	6.9	8.24	1.95	High Peak and Core
5	2.69	7.23	2.23	High Core, Peak, Valley
6	6.16	10.1	1.18	Very High Core, Peak

Interest for more comprehensive evaluation. The Region of Interests is detailed below:

Each appraiser has visually rated above mentioned 4 Region of Interests for each printed sheets. And under each trial combinations 3 sheets has been rated. Therefore total 12 Readings for against each trial combination by each appraiser. However average rating against each of the trial combinations by each of the appraisers has been shown below.

1. Blue Tint- Cyan Magenta Vignette Trapping

2. Blue Solid- Cyan Magenta Solid Trapping

3. Green Solid- Cyan Yellow Solid Trapping

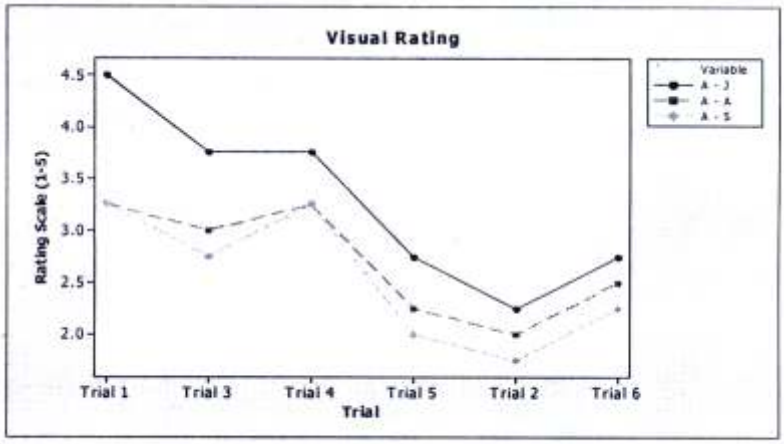
4. Grary Balance Patches

As it was expected, Trial Combination 2 has demonstrated lowest vivisual rating by all the appraisers indicating, since uniform print lay with good reproduction of both Solid and Vignettes have been achieved. At the same time it is worth noticing that Trial Combination 1 and 3 have been rated poor by all the appraisers, due to poor print lay with non uniform Solid and patchy vignette reproduction.

Discussion

Strong correlation is observed between the findings from topography analysis and print quality. All these analysis is indicating robust performance of Trial Combination 2 (Coating Recipe A + 2 IR Dryer) compared to other trial combination.

Coating Recipe made different grade of pigments and regulated Infra Red Drying have been found to significantly impact the coating layer structure.



Summary of Visual Assessment of Print Quality

Certain grades of pigments without IR drying of Coating have resulted in very non –uniform surface texture – high peaks and Valley structure which has eventually resulted in poor print lay & appeal. Whereas on the contrary certain grades of pigments in combination with regulated IR drying have lead to extremely uniform coating layer structure and hence superior print quality have been achieved.

CONCLUSION

This paper has dealt effectively in understanding the impact of Coating recipe made with different Pigments types along with controlled and regulated Infra Red Drying of online Blade Coated folding box board; upon the surface topography and microundulations in terms of peaks & valley structure of the coating surface. At the same time impact of nanoscale microundulations of the coating structure upon the visual print appeal have been established.

It has been observed that uniform surface topography with narrow distribution of peaks and valleys have been achieved Coating recipe A when used in combination with two rows of Infra Red Gas Dryer. And consequently superior print appeal have been achieved with this trial combination. Achieveing such nature of Coating layer Structure is the most desirable, especially when graphic demands are very high,. Thus a careful selection of pigment grades alongwith regulated Infra Red Drying can maximize print performance, just by rationalizing surface topography.

ACKNOWLEDGEMENT

I convey my sincere thanks to the entire Technical and Paper Machine team of ITC LIMITED, Papeboards & Specialty Papers Division, Unit: Bhadrachalam.

REFERENCES

Taylor Hobbson – Surface Texture Parameters
www.taylor-hobson.com
Relative advantage of Topography and Profilometry –
www.digitalsurf.fr
Richard Gagnon – Reducing Back Trap Mottle in Multi Layer Coating Systems, TAPPI 2006 Coating & Graphic Arts Conference
Helmut Kipphan – Handbook of Print Media, Heidelberg 2nd Edition X-Rite, A Guide to Understanding Graphic Arts Densitometry www.xrite.com
SAPPI Knowledge Bank – Mottling Mottled Impression
www.sappi.com