DOI 10.14622/Advances_49_2023_02

A static compression study on the lateral pressure variations of flexo post-print on corrugated board

Li Yang, Hans Christiansson, Anni Hagberg and Cecilia Rydefalk

RISE – Research Institutes of Sweden, pulp, papermaking and packaging, Drottning Kristinas väg 61, 11428 Stockholm, Sweden
E-mails: (li.yang, hans.christiansson, anni.hagberg, cecilia.rydfalk)@ri.se

Short abstract

A method for evaluation of lateral pressure variation of flexo post-print on corrugated board has been developed. Material sandwiches of print plates and corrugated boards were prepared with Tekscan sensor matrix being embedded in between the print plate and the corrugated board. The material sandwich was compressed by a Universal Testing Machine (UTM). With help of calibration, the pressure signals (0–255) of the sensor matrix were converted to the SI units, i.e. N/m^2 (Pa) or kPa. Lateral pressure variations inherent to the fluting structure of the corrugated board could thus be analysed. Seven commercial corrugated boards and two print plates (one hard and one soft) were involved in the study. It was found that the tensile stiffness of the top liners, especially in short-span, exhibited very strong and negative correlation with the pressure variations.

Keywords: stripiness, banding, tensile stiffness, bending stiffness.

1. Introduction and background

Print stripiness or banding is often a quality concern of flexo post-printing on corrugated boards. It appears as periodic density and/or gloss variations parallel to the flutes. The underlying causes were studied by several researchers with experimental and numerical means. Holmvall and co-workers (Holmwall and Uesaka, 2007; 2008; Holmwall, 2010) reported their studies of nip mechanics in flexo post-printing. In these studies, non-linear finite element models were constructed in both corrugated board and halftone dot scales to study the nip mechanics. Variations in nip pressure inherent to the fluting structure of the corrugated boards were found to be responsible for the stripiness. Hallberg Hofstrand (2006) measured the pressure variation with the Tekscan pressure sensing device and studied the influence of print forms on stripiness in flexo post-print using an IGT F1 Printability Tester. They concluded that a higher local contact pressure on the fluting tips than in the fluting valleys is the major cause of print banding as it leads to a higher ink transfer to the fluting tips than to the valleys. Thorman and Sandin (2020) introduced a calibration method for the Tekscan pressure sensing system. After the calibration, the Tekscan pressure signals (0–255) can be converted to international system of units (SI) in Pa or kPa (kilo pascal).

Our hypothesis is that the lateral nip pressure variation depends on the resistance of the top liner towards tensile & bending deformations. The goal of the work is to verify or falsify the hypothesis and to get in-depth understanding of the relationship between the topliner properties and the stripiness.

The study for the hypothesis verification consists of three steps:

1. Static compression – the material sandwich consisting of the corrugated boards together with the print plate and the pressure sensor matrix were compressed by a metal plate of a universal testing machine (UTM).
2. Dynamic compression – the material sandwich was compressed by the pressing cylinder of an IGT-F1 lab press without ink.
3. Print verification – the corrugated boards were printed with the IGT-F1 lab press.

This work presents the major findings obtained in the first step, namely the static compression situation. The other parts will be published elsewhere.

2. Materials and methods

2.1 Corrugated boards and polymer plates

Seven commercial corrugated boards of type B and two print plates were involved in this study (Table 1). The corrugated boards were made of topliners of different grades and different grammages and two different fluting media denoted as FM1 and FM2, respectively. The print plates have the same thickness but different Shore A values and colours.

Table 1: Parameters of the corrugated boards and print plates

Corrugated boards			**Polymer plate**		
Sample	Topliner (g/m^2)	Fluting media	Name (color)	Thickness (mm)	Hardness (Shore A)
WT1	Double coated (145)	FM1	Asahi DSE (red)	4.7	34
WT2	Double coated (175)	FM1	Flint FAC (blue)	4.7	32
WT3	White top (175)	FM1			
WT4	White top (145)	FM1			
WT5	Pure white (110)	FM2			
WT6	White top (135)	FM2			
WT7	White top (175)	FM2			

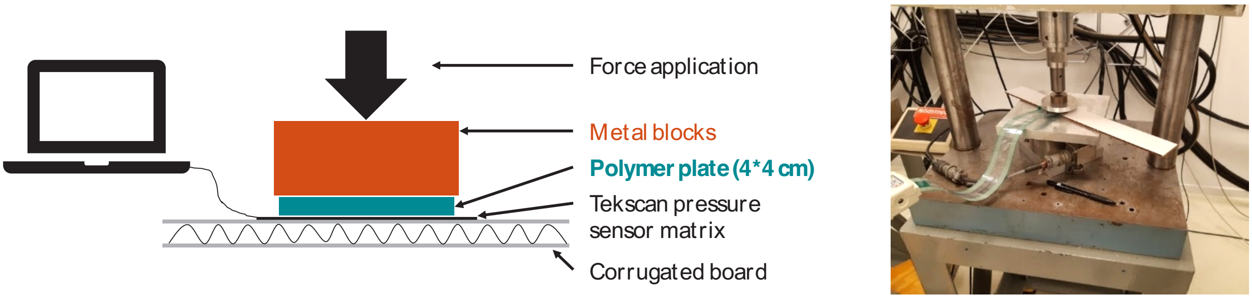
2.2 Measurements of the tensile stiffness

Tensile stiffness of the seven topliners were measured with the UTM system equipped with pneumatic grips. Short-span tensile stiffness (span 5 mm) was measured as it may be more relevant for the study because the top liner is “fixed” in position by gluing onto the fluting tips of the corrugated boards. Ten measurements were made for the short-span tensile stiffness of each topliner. Table 2 lists the tensile stiffness values of the topliners used in the respective corrugated board samples WT1 through WT7. Columns 3 and 4 are the means of the tensile stiffness values and their standard deviations. Column 2 is the strain corresponding to the tensile stiffness values.

Table 2: The tensile stiffness values (means and standard deviations) of the topliners and the corresponding strains where the measurements were made

Sample	**Strain (%)**	**Stiffness (KN/m)**	
		Mean	Std
WT1	2.87	989.14	21.59
WT2	2.96	1 181.12	53.70
WT3	3.58	1 233.10	54.87
WT4	3.34	958.58	35.63
WT5	3.45	797.99	32.30
WT6	2.78	1 212.82	51.93
WT7	3.38	1 374.00	57.47

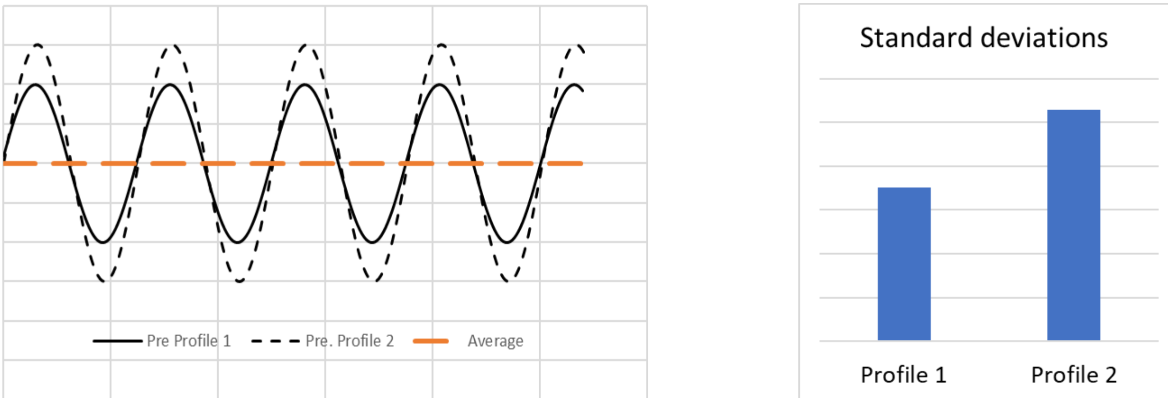
2.3 Measurement of the pressure profile



a) b)

Figure 1: Illustration (a) and the measurement setup (b) of compression test using a UTM

Figure 1 illustrates the setup of the pressure measurement of a material sandwich. The material sandwich consists of a piece of corrugated board at the bottom, a polymer plate on top, and the pressure sensing matrix (from Tekscan Inc., USA) in the middle. The sensor matrix possesses 44 × 44 = 1 936 sensor cells, equal number in MD and CD of the corrugated board. The center-to-center distance of two adjacent sensor cells is about 1 mm. The signals from the pressure sensor cells are transferred to the computer. With help of calibration, the pressure signals (0–255) from the sensor matrix are converted into Pa or kPa.

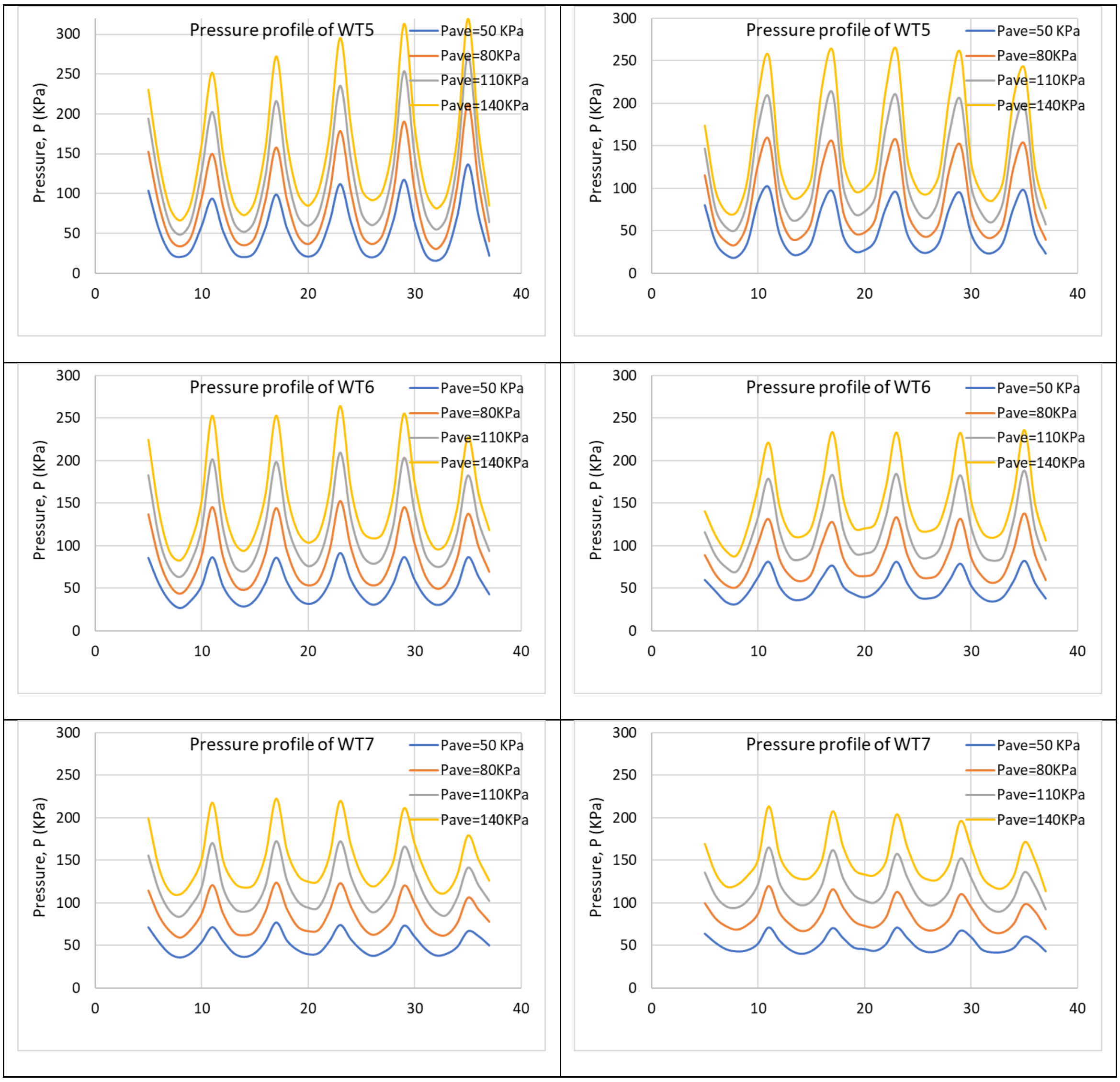


a) b)

Figure 2: Two pressure profiles (a) having the same average or nominal pressure (orange dashed line) but different amplitudes and standard deviations (b)

2.4 Analysis of pressure variation

Considering the geometrical characteristics of the corrugated board, we first took the average of the readings from the sensor cells in each row along the CD or the direction parallel to the flutes. The measured data was thus degenerated into one dimensional, e.g., pressure variation profile in MD. Figure 2 depicts two pressure profiles (Figure 2a) after the averaging in CD and their corresponding standard deviations (Figure 2b). Obviously, these two profiles have different amplitudes of pressure variation even though their nominal pressures (averages) are identical. For a sine-shaped periodic profile, the standard deviation of the profile is proportional to its amplitude. Thus, the variations can be well represented by their standard deviations. For meaningful compressions, pressure profiles corresponding to four nominal pressures, [50, 80, 110, 140] kPa, are presented in the next section.

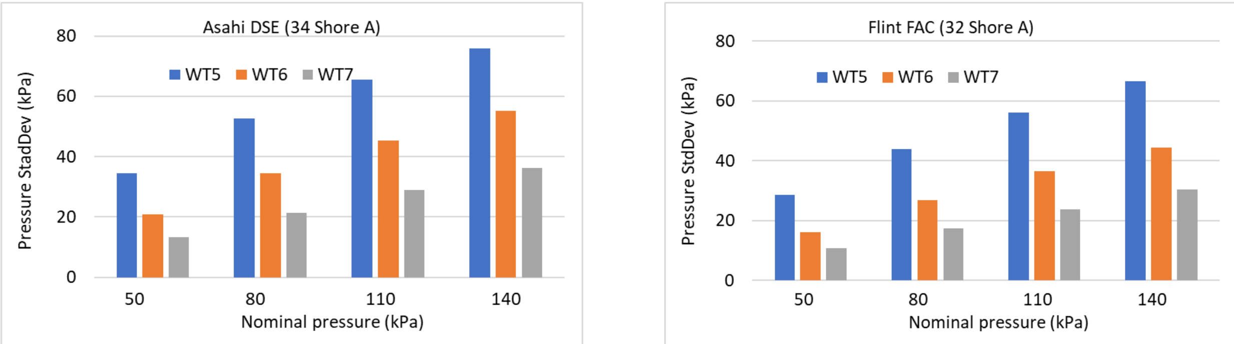


a) b)

Figure 3: Pressure profiles at four nominal (average) pressure levels, [50, 80, 110, 140] kPa; with the harder (Asahi) polymer plate (a); and with the softer (Flint) polymer plate (b)

3. Results and discussion

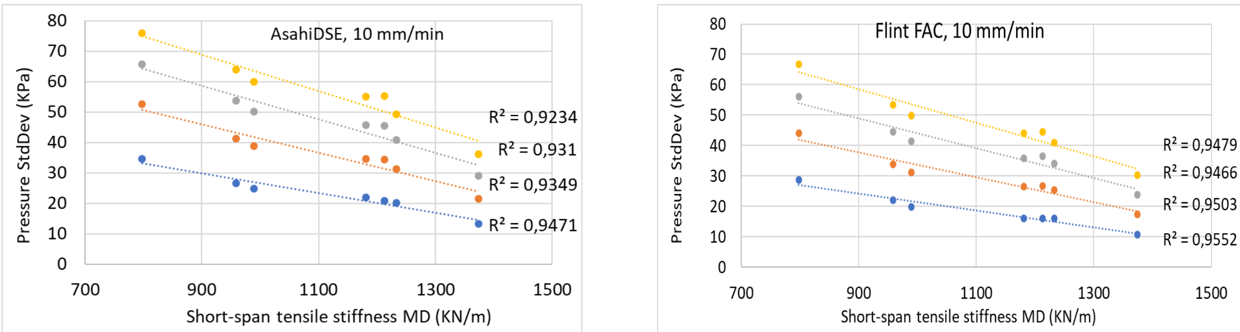
Figures 3 shows as an example of the pressure profiles of three corrugated boards, WT5 – WT7, at four nominal (average) pressures, [50, 80, 110, 140] kPa. Their corresponding standard deviations are shown in Figure 4. It is obvious that the amplitudes of the pressure variations increase with increasing nominal pressures. i.e. the higher the nominal pressure, the greater the pressure variation amplitude. Additionally, the amplitudes and the profiles differ significantly from one sample to another. As these samples were made of the same fluting medium but different topliners, one may thus attribute the differences to the topliners' properties. Furthermore, compared to the profiles in the right column (using the softer print plate, Figure 3b), the amplitudes of the pressure profiles obtained with the harder print plate (left column, Figure 3a) are generally higher. In other words, the pressure variation was reduced when the softer print plate was used.



a) *b)*

Figure 4: Pressure variations (standard deviations) of the pressure profiles shown in Figure 3; with the harder (red) polymer plate (a), and with the softer (blue) polymer plate (b)

Figure 5 shows the relationships between the pressure variation and the short-span tensile stiffness of the top liners. The two figures correspond to experiments with two polymer plates. The four datasets in each of the subfigures, from bottom to top, correspond to four nominal pressure levels, [50, 80, 100, 140] kPa. The seven data points in each dataset correspond to the seven corrugated board products. The very high R^2 values indicate very strong correlation between the pressure variation and the short-span tensile stiffness of the top liners.



a) *b)*

Figure 5: Correlations of the pressure variation with the short-span tensile stiffness of the top liners; with the harder (Asahi) polymer plate (a), and with the softer (Flint) polymer plate (b); the dots and lines from bottom to top correspond to the nominal pressures [50, 80, 110, 140] KPa, respectively

4. Conclusion remarks

This study confirmed the hypothesis that the topliner's mechanical properties, particularly the short-span tensile stiffness, have indeed strong impacts on the lateral nip pressure variation in flexo post-print. The R^2 values ranging between 0.92 and 0.96 indicated extremely strong correlations between the lateral presser variation and the short-span tensile stiffness of the topliners, regardless the grades or detailed material compositions of the topliners. This is significantly higher that the R^2 values for the correlation with the topliners' grammage (not show), ranging between 0.64 and 0.78.

The precedingly stated findings have been further studied in the dynamic compression situation using an IGT-F1 lab press and verified by lab printing where stripiness propensity of the lab prints. Detailed results of these studies will be published elsewhere.

Acknowledgements

DS Smith, Metsä Board, Mondi, and Stora Enso are gratefully acknowledged for financial support and providing the corrugated boards samples.

References

Holmvall, M. and Uesaka, T., 2007. Nip mechanics of flexo post-printing on corrugated board. *Journal of Composite Materials*, 41(17), pp. 2129–2145. https://doi.org/10.1177/0021998307074135.

Holmvall, M. and Uesaka, T., 2008. Striping of corrugated board in full-tone flexo post-printing. *Appita Journal*, 61(1), pp. 35–40.

Holmvall, M., 2010. *Nip mechanics, hydrodynamics and print quality in flexo post-printing*. PhD thesis. Mid Sweden University, Sweden.

Hallberg Hofstrand, E., 2006. *Flexographic post-printing of corrugated board: contact mechanics and print quality*. PhD Thesis. Karlstad University, Sweden.

Thorman, S. and Sandin, S., 2020. *Technique for characterisation of lateral pressure variations of corrugated boards: Bioeconomy Report No: 80*. Stockholm: RISE.