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Case study
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Influence of paperboard production on web movement and register quality in printing process

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Abstract

Register quality is often influenced by challenging web runnability. For fiber-based materials like paperboard it can be originated in the boardmaking process and tried to be compensated by web guiding and register control systems in printing process. Within an interdisciplinary research cooperation with different participants along the value chain of paperboard packaging production, the influence of different paperboard production conditions and register control strategies on web movement and register quality in a production scale gravure printing machine was performed in this study. Based on different boardmaking conditions, 13 different paperboard qualities were produced and each printed with 3 different register control strategies. The resulting register quality in cross direction (CD) and machine direction (MD) were measured as well as web movement, web tension and web moisture with several sensors along the printing machine. To assign the root causes of paperboard-induced web movement to boardmaking conditions, mechanical properties like tensile stiffness index in MD and CD and tensile stiffness orientation of the paperboard material have been measured and compared with data on web movement in the printing press. Further, web edge data were analyzed in frequency domain, to assign characteristic frequency components to their different mechanical root causes in boardmaking and printing process. It was found that CD position on tambour is the most influential board side parameter on lateral web movement and register quality. The lateral web shift differs significantly for middle and edge reels. Main reason for misregister in this study was attributed to board side slow lateral web movements with increasing amplitudes along the printing press. A register control strategy with an increasing gain per printing unit was most effective to improve register quality for this runnability behavior.

Keywords: board production conditions, register control strategies, web runnability, lateral web movement, misregister

1. Introduction and background

A key quality parameter of a printing product is its register quality. It means printing the right color at the right place. The register quality affects sharpness and color appearance of a multicolor print. The visibility of misregister is dependent on various influences like ink color, image or screening technology. In general, misregister can be defined as a relative misalignment of printing cylinder to the moving web and the previous printed pattern in cross direction and in machine direction (Kang, Lee and Shin, 2010). This two-dimensional alignment is the task of the register control system in a printing machine in order to get a printed image of high quality. In gravure printing machines, typically, the register controller aligns the printing units to the web, based on register mark measurements.

Most of previous case studies regarding paper web runnability have been carried out for offset printing processes with light-weight coated (LWC), uncoated and super-calendered (SC) papers for newsprint or commercial print goods.

Parent and Hamel (2013) presented how paper mills have worked on improving paper properties to reduce web lateral instability in different case studies with different paper grades and trials in pressrooms and in laboratory.

In two case studies from Parola, et al. (2003), and Paukku, Parola and Vuorinen (2004), data from different paper mills and one printing press were gathered and combined into reel specific key figures and analyzed with a proprietary data mining software. They focus on clarifying the reasons for runnability issues with special attention to lateral web movement and web widening.

Shields, et al. (2018) studied papermaking reasons for lateral shift of a moving paper web made from one particular paper machine on a specific heatset web offset printing press. They tested 11 different paper qualities regarding runnability in this press and regarding water absorption in laboratory. Fiber orientation was found as the most important factor affecting lateral web movement in printing press.

Case studies on gravure printing presses were perfomed by Parola with coworkers but even with SC and LWC paper grades. They found that the cross direction (CD) position of the reel in paper machine is one of the most influential feature regarding variations in web tension profiles and runnability issues (Parola and Beletski, 1999; Parola, et al., 1999).

To accommodate certain reel to reel variability in daily print production, it is a common practice that printers sort the reels by its CD position in paper machine and running them in sequence if they have this information from the producer. Paukku, Parola and Vuorinen (2004) argue that issues with paper side uniformity in machine direction (MD) within a reel have to be solved in paper mills.

Unlike in other studies, in this publication both web runnability and register quality were analyzed. Substrate side and register controller side reasons on register quality were separated through a corresponding experiment design. Further, our study was performed at a production-scale gravure printing press and with multiply paperboard material for folding boxes. To our knowledge, this type of study has not been performed before. Due to its thickness, stiffness and multiply structure it is assumed that this web material has probably different mechanical properties and interaction within the printing process than thin offset papers.

2. Materials and methods

2.1 Substrate manufacturing

The printing trials were performed with a 722 mm width, 3-ply solid bleached board, based on chemical pulp with a grammage of 240 g/m^2, a thickness of 305 µm and a one side coating of approx. 20 g/m^2. The outer plies consist of a virgin fiber hardwood/softwood mixture, while the middle ply comprises a virgin fiber mixture of softwood and broke. In contrast to normal cardboard production run, for the print trials two process conditions in board machine were varied experimentally during the production of the board:

- In order to variate the tensile stiffness (fiber) orientation (TSO_{Angle}) and the tensile stiffness index (TSI) ratio between MD and CD, the speed differ-

Table 1: Specification of reference reel (reel 1)

Specification	Value	Tolerances	Method
Grammage (g/m^2)	240	± 5	ISO 536
Thickness (µm)	305	± 5	ISO 534
Front surface roughness (µm)	1.1	≤ 1.4	ISO 8791-4
Back surface roughness (µm)	4	≤ 5.5	ISO 8791-4
Moisture Content (%)	5.7	± 1	ISO 287
Bending stiffness L&W 5° MD (mN)	18.5	–	ISO 5628
Bending stiffness L&W 5° CD (mN)	7.8	–	ISO 5628
Bending resistance L&W 15° MD (mN)	215	−15	ISO 2493
Bending resistance L&W 15° CD (mN)	90	−15	ISO 2493
Bending moment Traber 15° MD (mNm)	10.4	−15	ISO 2493
Bending moment Traber 15° CD (mNm)	4.3	−15	ISO 2493
Tensile strength MD (kN/m)	18.5	–	ISO 1924-2
Tensile strength CD (kN/m)	10	–	ISO 1924-2
Tearing resistance MD (mN)	2 750	–	ISO 1974
Tearing resistance CD (mN)	3 100	–	ISO 1974

ence between suspension jet flow and forming wire (Δv) were set at three levels: low (2 m/min), medium (6 m/min) and high (10 m/min).

- In order to influence the homogeneity of the fiber distribution, a wire shaker on the middle ply was operated with a frequency of approximately 8 Hz at a production speed of 500 m/min.
- For each of the above 6 combinations of process conditions, one roll from the edge and one from the middle of the board machine were taken.

In addition, a reference reel (reel 1) from a normal board production run was evaluated. In total, 13 different reels were evaluated.

The MD variation of the web properties TSI_{MD}, TSI_{CD}, TSO_{Angle}, thickness, and grammage are most important for the behavior of the web in the printing press (Parent, 2015). These properties were measured over the last 200 m of three of the randomly chosen roll qualities at the mill every 40 mm (corresponding to a wavenumber of 25 m^{-1}) according to the measurement principle described in Loewen (2004).

The experimental cardboard is based on a reference production (reel 1) with specifications (measured in test climate 23 °C and 50 % relative humidity) listed in Table 1. Experimental cardboard reels differ from this standard production. So the specifications are not fully valid for experimental cardboard reels used in the print trials. The table only gives a rough impression of the structure and nature of the used substrates.

2.2 Printing machine

Trials were run on a 178 m long production scale roll-to-sheet rotogravure press with 11 printing units (PU), numbered 2 to 12, and embossing unit (EMB) which is driven by a mechanical line shaft (Figure 1). The printing machine consist also of an unwinder, a tension control system, a web guiding system Compact Guide (BST eltromat International, 2017a; 2017b) for compensation of lateral web displacements of the unwinder., followed by the infeed pull unit. In the 134 m long printing section are 11 equal PUs. Inks are dried directly after each PU. After PU8 there is an edge cutting unit for cleaning the web edge for packaging converting processes in the sheeter. After the printing section, there is an optional outfeed pull unit for the sheeter or the rewinder.

2.3 Register controller

The register is controlled by two-dimensional feedback register control system regi_star 20 (BST eltromat International, 2015), which is based on a discontinuous 3-state controller with hysteresis and dead band. The register is measured in each PU over one triangle register mark per print cylinder rotation (printing length) on the operating side (OS), see Figure 2. Depending on the control strategy, this measurement is referenced to the first color or to the previous color. This value represents the control systems data input as the control deviation.

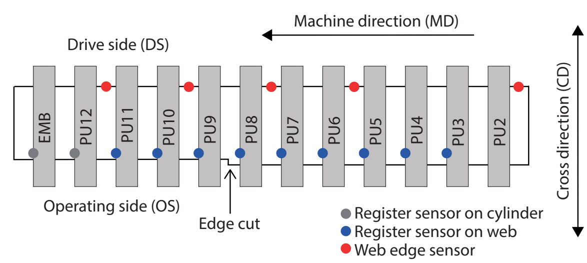

Figure 2: Principal top view drawing of printing machine with web edge and register sensor positions

The MD register is set by a compensator actuator which lengthens the web span between printing units. The CD register is set by a CD movement of the printing cylinder.

For the trials the CD control strategies were variated with 5 different parameter settings marked A to E (Table 2), with constant deadband of 0.02 mm, hysteresis of 0.02 mm and without increasing gain (D-portion equal 0). For MD register control, only the default setting and a deactivated controller was used. The measurements are referenced to the first color or to the previous color, depending on the used control strategy. A praxis relevant maximal register tolerance of ± 0.15 mm in CD and MD was defined for the trial.

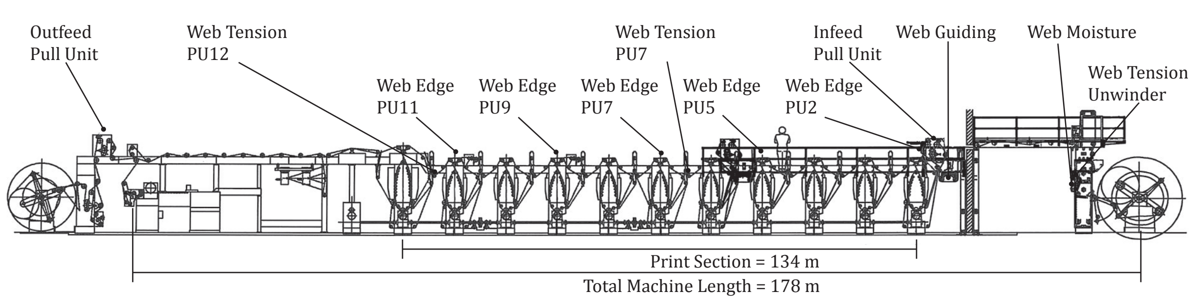

Figure 1: Production scale gravure printing machine equiped for experiments

Table 2: List of register control settings per control strategy

Controller setting	Strategy	Time const. low pass filter	Feedback const. [ms]	Feedback gain [ms]	Ref. color
A	default	3	800	950	first
B	off	–	–	–	–
C	low pass filter	4	950	750	first
D	increasing gain per PU	3	800	450 +200 per PU	first
E	sequential controlling	3	800	450 +200 per PU	previous

2.4 Print job

The trial was performed by running a 10 color and embossing job with 722 mm web width and 32 products per sheet. The first active PU was PU3 and cylinder diameter was 309.24 mm (corresponds to a rapport of 972 mm). Because of the big number of products per sheet, the ink is homogeneously distributed in MD and CD.

In general, ink specific parameters like ink absorbance, ink area coverage or ink sequence for this type of substrate are considered negligible. One reason is that the printed ink layer thickness with approx. 1–5 µm is very small relative to cardboard thickness of 305 µm. Another reason is that ink has not time to penetrate into the cardboard, due to direct drying after each printing unit and the coated surface of the substrate. This is fundamentally different to offset case studies with thin offset papers. This assumption is supported by daily production run observations for this machine. Web run issues occur more frequently with thicker substrate materials than for thinner, independent on ink sequence, ink viscosity and print job. Nevertheless the specific ink sequence, ink types and ink flow rates (viscosities) used in the experiment are listed in Table 3.

Table 3: PU sequence and properties of inks used

Unit	Color	Ink type	Flow rate [s]*
PU2	–	–	–
PU3	spot color	solvent based	27
PU4	magenta	solvent based	24
PU5	cyan	solvent based	25
PU6	yellow	solvent based	25
PU7	spot color	solvent based	28
PU8	spot color	solvent based	29
PU9	black	solvent based	25
PU10	lacquer	solvent based	29
PU11	lacquer	UV curing	31
PU12	lacquer	UV curing	23
EMB	embossing	male/female	–

*(3 mm flow cup DIN 53211)

For a meaningful analysis, only the register controller settings were changed. All other printing conditions were kept constant:

- Web speed: 2.5 m/s
- Print cylinder pressure: 12 kN
- Dryer temperature: ~85 °C
- Pull unit forces: 1st pull unit = 590 N; 2nd pull unit = 650 N

For this study, the printing machine was specially equipped with the following sensors:

- five web edge sensors CLS Pro 600 (BST eltromat International, 2017c), on the drive side (DS) (Figure 2) after printing units 2, 5, 7, 9, 11 with sampling rate of 100 Hz and resolution of 0.005 mm
- four web tension measurement rollers with strain gauges at the unwinder, 1st pull unit, PU7, PU12 and EMB
- one infrared web moisture sensor NDC IG710e (NDC Infrared Engineering, 2010) directly after unwinding

2.5 Trial plan

The different parameters in the boardmaking process and print process described before, led to trial plan shown in Table 4, where each parameter combination is denoted with an identification number (ID). Each reel was started and ended with the default register controller setting A, to run the reel change with the same controller setting.

2.6 Data recording and pre-processing

All printing machine measurements were collected from a process data recording system (iba System, 2019) with a rate of 100 Hz, independent of the real sensor specific measurement rate. In this context missing values were filled with the last true measurement value. For a web speed independent data analysis, the

Table 4: Trial plan with all combinations of boardmaking conditions and register control strategies in CD and MD, denoted with experiment IDs

Boardmaking Process				**Reel number**	**Printing Process**						
Boardmaking conditions					CD and MD register control strategies						
Name:	Δv	WS	CDP		Name:	A	B	C	D	E	A2
Parameter:	Jet/wire Δv [m/min]	Wire shaker	CD position on tambour		MD:	Default	Off	Default	Default	Default	Default
					CD:	Default	Off	Low pass filter	Increasing gain	Previous color ref.	Default
Value:	Default	Off	Middle	1 (ref.)	Experiment ID:	1	2	4	5	6	7
	2	On	Middle	2		10	11	13	14	15	16
	2	On	Edge	3		19	20	22	23	24	25
	2	Off	Middle	4		28	29	31	32	33	34
	2	Off	Edge	5		37	38	40	41	42	43
	6	Off	Middle	6		46	47	49	50	51	52
	6	Off	Edge	7		55	56	58	59	60	61
	6	On	Middle	8		64	65	67	68	69	70
	6	On	Edge	9		73	74	76	77	78	79
	10	On	Middle	10		82	83	85	86	87	88
	10	On	Edge	11		91	92	94	95	96	97
	10	Off	Middle	12		100	101	103	104	105	106
	10	Off	Edge	13		109	110	112	113	114	115

sensor data were first aligned via their time constant τ, according to its positioning in the printing machine L and the web speed v (Equation [1]).

$$\tau = \frac{L}{v} \quad [1]$$

Then they were resampled to a new discrete base with a sampling rate of 0.025 m (corresponding to a wavenumber of 40 m^{-1}). In this way the comparison of web movement frequencies in print process and boardmaking process can be done much easily. The register error measurements from setting E were summed up over CD and MD, to make these data comparable to the data of the other register strategies with first color as it's reference. To eliminate non steady-state conditions due to changes of register control strategy, we eliminated the first and the last 20 % data of each experiment ID.

2.7 Statistical evaluation

The pre-processed data were evaluated quantitatively mainly by two statistical values. Due to the steady-state process conditions without any machine operator intervention it was expected that register data and web movement data are normal distributed around their mean value. Each experiment ID consists of approximately 500 m steady state condition process data. Representative for each experiment ID, we checked register, web edge, web tension and web moisture data of ID1 at PU9 for normal distribution with probability analysis like the example in Figure 3.

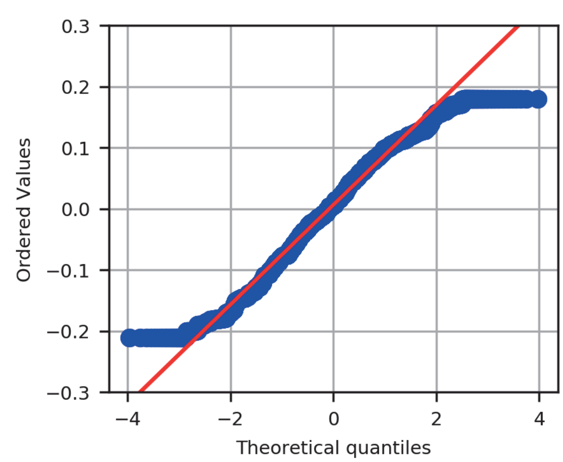

Figure 3: Exemplary probability plot of a pre-processed experiment ID data sample (CD register data of ID1)

Due to the normal distribution and the amount of data, it is permissible to calculate statistical quantities such as the arithmetic mean or the standard deviation (σ) with statistical certainty in order to derive statements about the lateral web shift or web movement.

2.8 Summary

Approximately 72 000 m of experimental paperboard material produced at 13 different process conditions were winded to 13 reels. These reels were then printed at steady-state conditions. The register quality was controlled with five different register control strategies and the lateral web movement was measured with five high-resolution web edge sensors. In addition, the web moisture and the web tension were also measured online.

All measurements had the following objectives:

- Quantify the influence of paperboard production parameters on:
  - Web movement characteristic along the printing press
  - CD and MD register quality depending on different register controller strategies

- Assign the root causes of paperboard-based web movements to board production

- Detect critical web movement wavelength for the register controller used

At the end, the most important quantitative statistical results will be summarized in a single table to assign the conditions in boardmaking process to the effects in printing process.

3. Results and discussion

3.1 Web runnability

The relative lateral web shift along the printing machine was calculated via the mean values per PU of the web edge data, relative to the data of reference reel 1. Only data with deactivated register controller (setting B) were used to get only the natural web movement without any impact of cylinder movements due to register controlling. Figure 4 shows the observed clear clustering of middle (solid black lines) and edge (dashed blue lines) reels. Furthermore, the relative web shift to the reference reel is approximately linear along the press.

The lateral web movement within the general lateral web position was quantified as standard deviation σ of the web edge data per PU. It was found that the web movement basically increases along the printing press (Figure 5). A clear clustering of middle and edge reels can also be observed here. The red line marks the praxis relevant register quality specification limit of 0.15 mm as comparative value.

3.2 Register quality

The CD register quality was determined analogously to lateral web movement via σ over printing units. This analysis was done for all control strategies starting with setting A (Figure 6) as default control strategy, B (Figure 7) as deactivation of register controlling and followed by the experimental strategies of C (Figure 8), D (Figure 9) and E (Figure 10). The red line marks the praxis relevant register quality specification limit of 0.15 mm again.

The CD register quality statistics show similar tendencies to web movement results. The error increases along the printing press and the same clustering of middle and edge reels can be observed in register quality. It becomes obvious that register quality is dependent on web movement characteristics. In our case, the CD register control strategy with the parameter set with the increasing gain (setting D) performed significantly better than the default control setting (setting A), which is optimized for a wideband material portfolio, working sufficiently for most of the production, but it is not optimized for special effects. The experimental setting C shows only slightly better results due to its low pass filter. Setting E as a control strategy, where the previous color is the respective reference color was completely out of tolerance. It underlines that this strategy does not work well for more than three colors, because of its accumulation of errors. In general, it can be assumed that an increasing gain of control can help to keep register error small for long printing machines with this kind of web movement characteristic.

- Regarding the influence of control strategies, setting D is best and setting E is worst for CD register quality.

- Regarding boardmaking conditions, edge reels show best and middle reels show worst register quality. No significant influence of the wire shaker or the jet/wire speed difference in CD register statistics could be observed.

In MD the register quality was nearly constant for activated register controller over all material qualities. Unlike for default CD register (Figure 6), no increasing σ can be observed (Figure 11), although the σ increase is significant for deactivated register controller (Figure 12). As expected, the reference reel shows the best natural runnability result in MD.

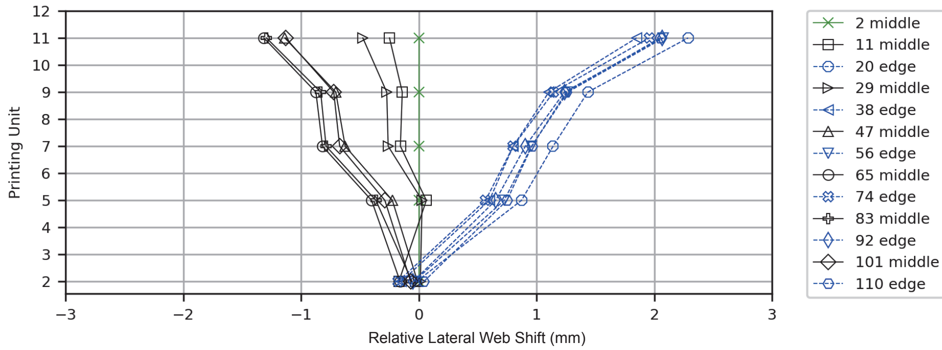

Figure 4: Natural lateral web shift along the printing machine shows clear difference in runnability for middle (solid black lines) and edge (dashed blue lines) reels relative to the reference reel (green)

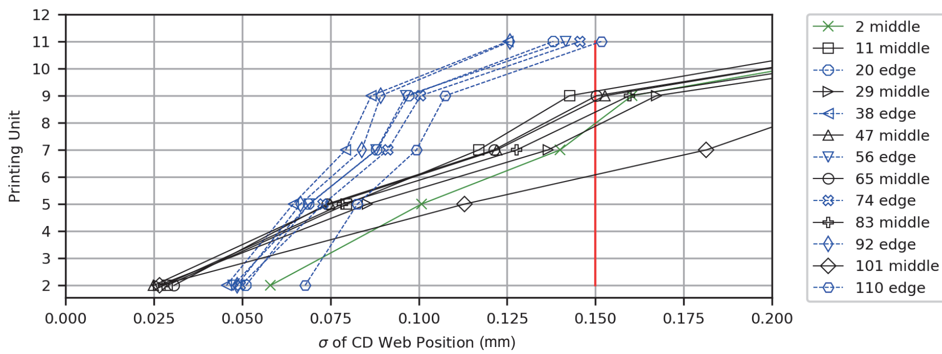

Figure 5: Natural lateral web movement along the printing machine shows clear difference for middle (solid black lines) and edge (dashed blue lines) reels with increasing deviations along the printing machine

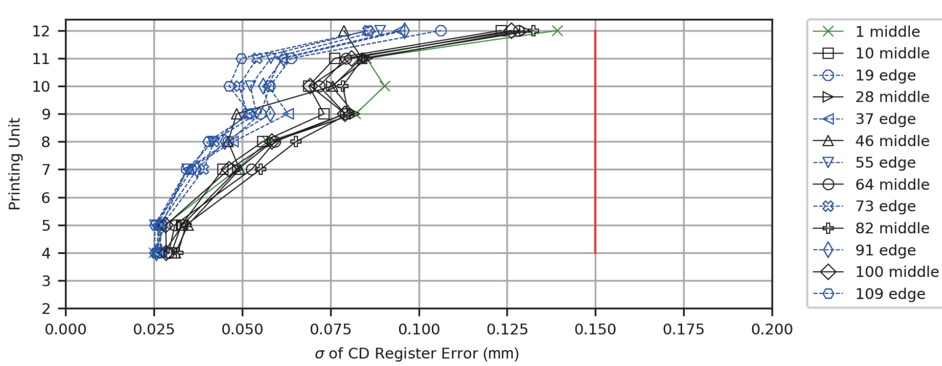

Figure 6: CD register quality standard deviation for register control setting A for middle (solid black lines) and edge (dashed blue lines) reels with increasing deviations along the printing machine

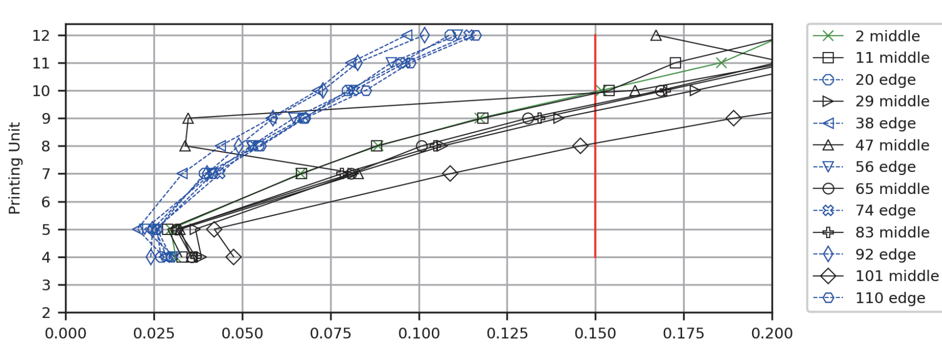

Figure 7: CD register quality standard deviation for register control setting B (natural lateral web movement) for middle (solid black lines) and (dashed blue lines) edge reels with increasing deviations along the printing machine

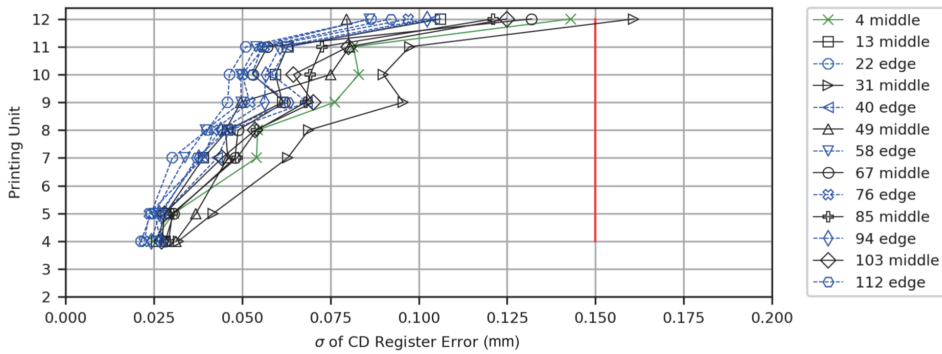

Figure 8: CD register quality standard deviation for register control setting C for middle (solid black lines) and edge (dashed blue lines) reels with increasing deviations along the printing machine

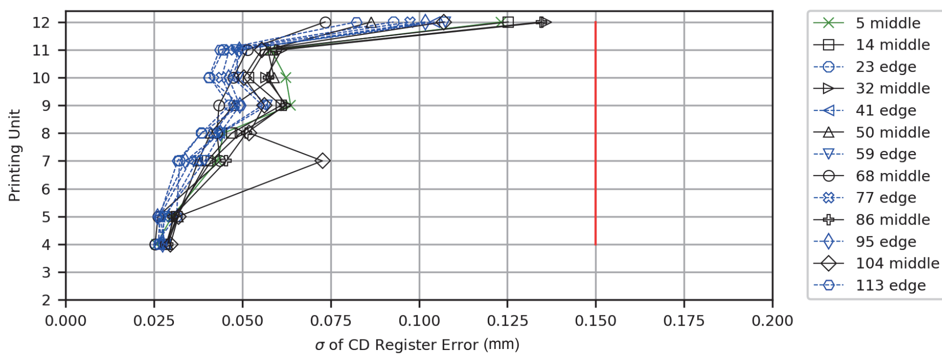

Figure 9: CD register quality standard deviation for register control setting D for middle (solid black lines) and edge (dashed blue lines) reels with increasing deviations along the printing machine

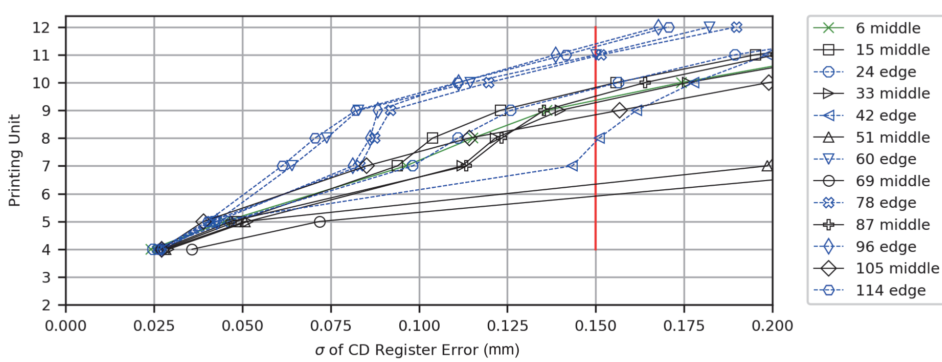

Figure 10: CD register quality standard deviation for register control setting E for middle (solid black lines) and edge (dashed blue lines) reels with increasing deviations along the printing machine

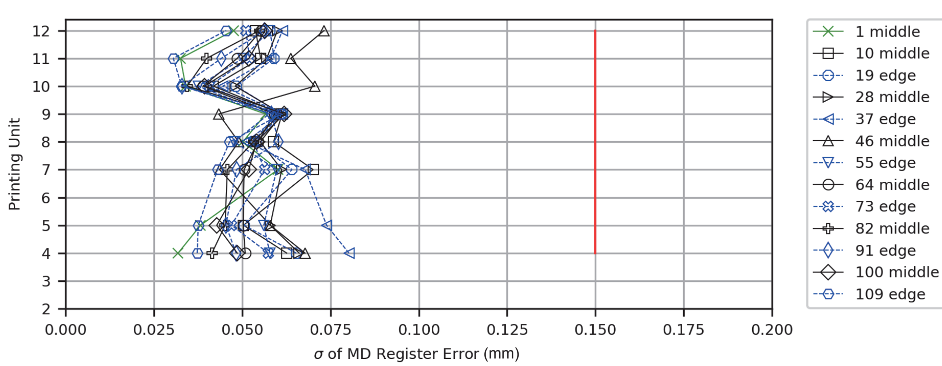

Figure 11: MD register quality standard deviation for register control setting A for middle (solid black lines) and edge (dashed blue lines) reels with similar deviations along the printing machine

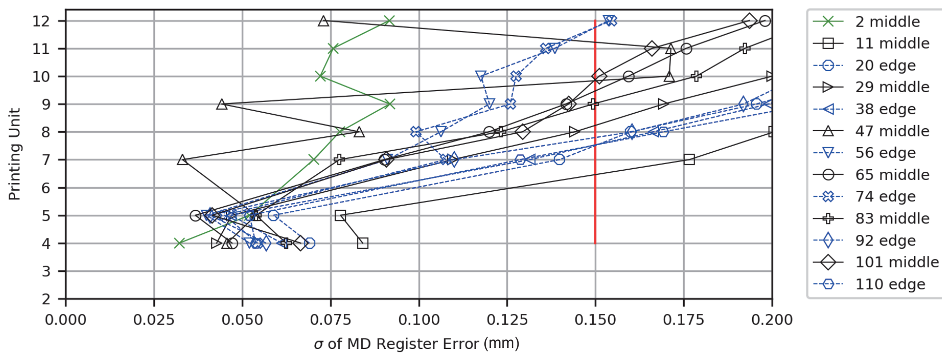

Figure 12: MD register quality standard deviation for register control setting B (natural lateral web movement) for middle (solid black lines) and edge (dashed blue lines) reels with increasing deviations along the printing machine

3.3 Influence of web moisture on web movement

The web moisture measurements in printing machine shows that middle reels had ~1 % more moisture than edge reels, except the reference reel 1 (Figure 13). This observation indicates that the quantities of lateral web movement might have something to do with inhomogeneous web moisture profile in board production.

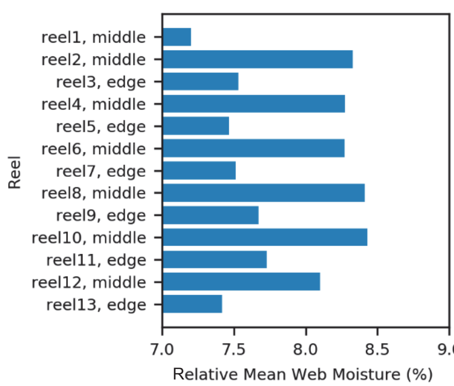

Figure 13: Detected mean web moisture shows clear correlation to CD position of reel on tambour

3.4 Influence of jet/wire speed difference on web tension

A further observation was, that the mean value of web tension in PU7 shows a slight increasing of tension with higher jet/wire speed difference (Figure 14).

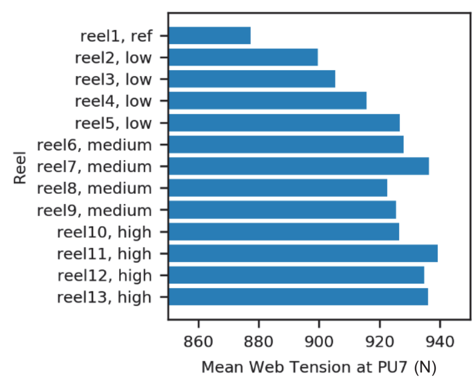

Figure 14: Mean web tension at PU7 shows slight correlation to jet/wire speed difference

This result can be explained by the corresponding TSI_{MD} values due to the different boardmaking conditions

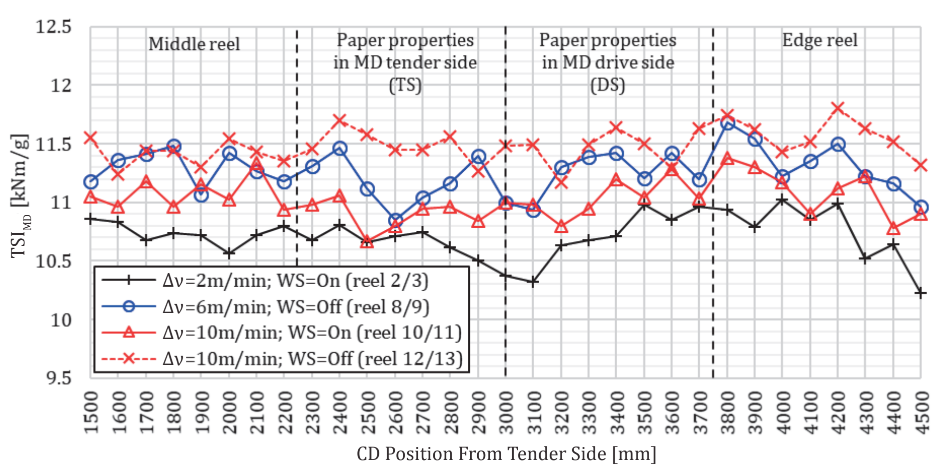

Figure 15: TSI_{MD} profile in CD shows significant influence of jet/wire speed difference and wire shaker (WS) on TSI_{MD} mean value

(Figure 15). As expected, the jet/wire speed difference influenced the TSI_{MD} Level. The higher the speed difference, the higher the TSI_{MD}. However, an activated wire shaker reduces the TSI_{MD} significantly. In addition, the measurements show a typical skew TSI_{MD} profile in CD for edge reels. It is assumed, that this behavior is the main root cause of the different lateral web shift in the printing machine for edge and middle reels.

3.5 Influence of wire shaker on web movement

It was found that the wire shaker parameters have a measureable effect on the fiber orientation. The arrow in (Figure 16) marks the peak in the spectra of reel 3 TSO measurements. The peak at wavenumber 0.8 m^{-1} (1.25 m wavelength) corresponds exactly to shaking frequency of the wire shaker in the board machine.

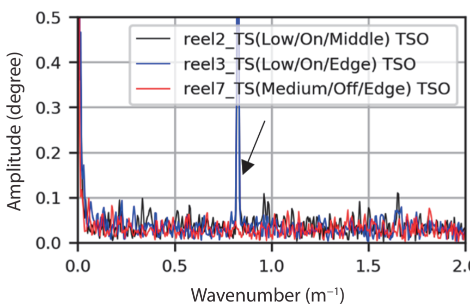

Figure 16: Frequency spectra of TSO_{Angle} in MD

The same peak was also found in web movement spectra of reels with activated wire shaker (Figure 17). But the amplitudes are too small to have a significant impact on the register quality. There are other, much stronger web movement frequencies, which could have a more relevant impact on the register quality. A comprehensive analysis of these frequencies in web edge data is beyond the scope of this work, but it will be part of future work.

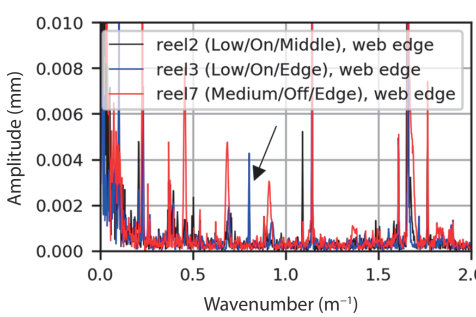

Figure 17: Frequency spectra for web edge data

3.6 Main reason for CD register effects

As most important reason for CD misregister in our study, we detected the web movement characteristics that were slower than 0.1 m^{-1} (corresponds to a wavelength of >10 m) with increasing amplitudes along the printing machine (Figure 18). These growing amplitudes in low frequency range can also be observed in CD register data (Figure 19).

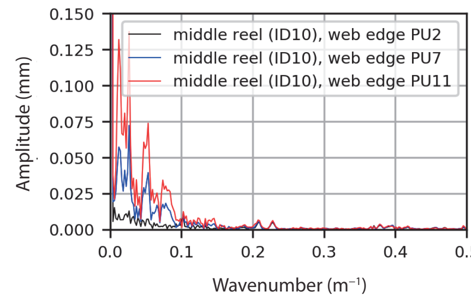

Figure 18: Growing low frequency amplitudes along printing machine in web edge data

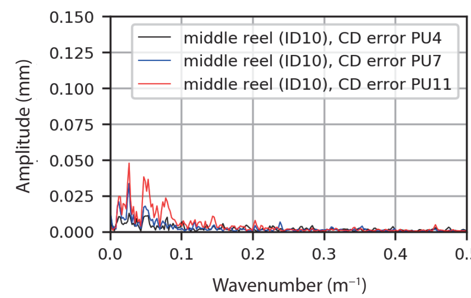

Figure 19: Growing low frequency amplitudes along printing machine in CD register data

The difference in movement behavior in frequency domain of middle reels (black) and edge reels (blue) were analyzed for all register control strategies and show the main reason for differences in web movement characteristic for edge and middle reels (Figure 20).

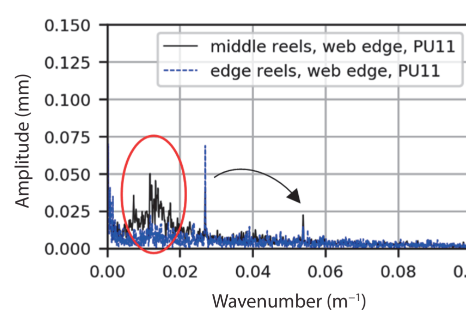

Figure 20: Frequency analysis of dominant slow web movements show significant difference between edge and middle reels

At ~0.015 m^{-1} (67 m wavelength) the spectra of middle reels show a characteristic noisy peak which is much higher than for edge reels. So it seems to be the main reason for differences in register quality between middle and edge reels. The peaks at ~0.025 m^{-1} (40 m wavelength) and ~0.053 m^{-1} (19 m wavelength) appear in both CD positions. It is assumed that the noisy frequency characteristic is originated in the three headboxes at the board machine, due to three paperboard layers. Troubleshooting these pulsations can now be searched for in the boardmaking process.

The most important quantitative results are summarized in Table 5. The table is divided into the boardmaking process and the printing process and shows the results regarding web runnability and register quality by meaningful statistical values, namely the arithmetic mean value (mean) and the standard deviation σ. Lower σ means less web movement or register error issues.

4. Conclusions

The key findings in our research are:

- CD position on tambour is the most influential board parameter on lateral web shift, lateral web movement and CD register quality.
- Jet/wire speed difference has only impact on MD register.
- Wire shaker affects the lateral web movement measurably but has no significant impact on register quality.
- Less lateral web movement results in better register quality for each register control strategy in general.
- The register control strategy with an increasing gain per printing unit resulted in improved register quality with the trial material.
- Board based slow lateral web movements with increasing amplitudes along the press were identified as the main reason for runnability and misregister issues.

In future work we will continue our research to:

- Clarify proportion of web movement within web edge data.
- Investigate dynamic frequency variations in web edge and register data over time.
- Assign frequency components to their root causes in boardmaking or printing process.
- Develop a concept to quantify the register controller efficiency in frequency domain for different web movement signals.
- Search for low frequencies in boardmaking process with noisy characteristic.
- Extend experiment design to evaluate influence of individual paperboard layer regarding headbox pulsation.

Table 5: Heatplot of most important quantitative results seperately in boardmaking and printing process

Boardmaking process					Printing process										
Production Parameter			Board props.		Web				CD Register					MD Register	
Jet/wire Δv	Wire shaker	CD pos.	TSI_{MD}	Reel	Rel. moisture	Tension (PU7)	Lateral shift (PU11)	Lat. movement (PU11)	A (PU11)	B (PU11)	C (PU11)	D (PU11)	E (PU11)	A (PU11)	B (PU11)
			kNm/g		%	N	mm	mm	mm	mm	mm	mm	mm	mm	mm
			mean		mean	mean	mean	σ	σ	σ	σ	σ	σ	σ	σ
x	off	mid.	x	1	7.19	877	0	0.248	0.09	0.19	0.08	0.06	0.22	0.03	0.08
low	on	mid.	10.6	2	8.33	899	−0.558	0.231	0.08	0.17	0.06	0.06	0.20	0.06	0.30
low	on	edge	10.6	3	7.53	905	2.114	0.138	0.06	0.09	0.05	0.04	0.19	0.06	0.24
low	off	mid.	x	4	8.27	915	−0.860	0.270	0.09	0.21	0.10	0.06	0.22	0.06	0.22
low	off	edge	x	5	7.46	926	1.654	0.125	0.06	0.08	0.06	0.05	0.20	0.06	0.25
med.	off	mid.	x	6	8.27	927	−1.435	0.245	0.08	0.20	0.08	0.06	0.26	0.06	0.17
med.	off	edge	x	7	7.50	936	1.938	0.141	0.06	0.09	0.05	0.05	0.15	0.05	0.14
med.	on	mid.	11.3	8	8.40	922	−1.442	0.245	0.08	0.20	0.06	0.05	0.62	0.05	0.18
med.	on	edge	11.3	9	7.67	925	1.809	0.145	0.05	0.10	0.06	0.05	0.15	0.05	0.14
high	on	mid.	11.1	10	8.73	926	−1.458	0.258	0.08	0.21	0.07	0.06	0.20	0.04	0.19
high	on	edge	11.1	11	7.72	939	2.013	0.125	0.06	0.08	0.06	0.05	0.14	0.04	0.23
high	off	mid.	11.5	12	8.10	935	−1.273	0.368	0.08	0.29	0.08	0.06	0.25	0.05	0.17
high	off	edge	11.5	13	7.41	936	1.842	0.151	0.05	0.10	0.06	0.04	0.14	0.03	0.29

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