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CORRELATION BETWEEN PAPER QUALITY AND CALENDER ROLL RUN-OUT

Pirttiniemi, J., Porkka, E., Kiviluoma, P. & Kuosmanen, P.

Abstract: *Thermal deflection of the thermo rolls can be source for unacceptable thickness and gloss variations occurring in the machine direction of the paper web. In this work correlation between paper quality and calender roll run-out was studied. Run-out of the thermo rolls was measured in production conditions by an accelerometer based method. In order to observe the quality variations in the paper web, paper sample analysis was carried out. Paper samples in machine direction were taken at same circumstances as the run-out measurements were carried out. According to the run-out measurements, bending of the thermo roll was significant. So called polygonal effect, caused by peripherally bored heating channels was also noticed. Notable correlation between roll bending and paper quality variation of the paper samples was found.*

Key words: paper machine, thermo roll, thermal deflection, gloss variation, thickness variation, paper sample.

1. INTRODUCTION

There are several factors that affect the quality of the paper. A modern paper machine is equipped with various finishing units e.g. coating units and calenders in order to produce better optical as well as printing properties. To accomplish these required properties paper is manipulated between two parallel rolls. The rolls are pressed together using hydraulic loading mechanism in order to achieve required pressure to paper web [1]. The contact area of these rolls is called a nip.

In calendering process two or more rolls are pressed together in order to generate conditions in the contact area where the paper web achieves desired properties. High pressure, high temperature and certain amount of moisture are used to make the process more effective. The temperature is controlled by heated rolls, i.e. thermo rolls. Thermal energy is transferred to the roll surface by peripherally bored heating channels inside the roll shell. When heated, manufacturing inaccuracy and inhomogeneous roll material can cause thermal deflection.

If the nip rolls have geometrical deviations the pressure in the nip varies causing runnability and quality problems in the paper. This common phenomenon is called barring. Barring causes different kinds of quality problems in the end product, such as MD variation in thickness, basis weight and opacity.

In calendering process, the surface structure of the paper can be controlled by changing nip pressure and temperature as well as by moisturizing. In calendering process it is important to remain the bulk on the required level. However, if the process parameters, such as the nip pressure, are varying during the calendering process, it will cause variation in the thickness and the structure of the paper. This may appear as visible defects and decreased strength in further processing like printing. To find out what effect the calender rolls have to the produced paper, it is essential to make measurements in process conditions.

In this study, the run-out of the thermo roll is measured and compared with the paper samples. Run-out of the thermo roll was measured in order to find out geometrical errors caused by thermal load. It was also important to know how these changes would affect the paper quality.

Most common troubleshooting methods are the analysis of the paper samples as well as the vibration studies and geometrical studies of the rolls. In-situ measurements are essential when defining the parameters for theoretical models and evaluating the phenomenon itself.

In order to solve the problems caused by barring, it is important to define and analyse the sources of the vibrations.

The method that was used to measure the run-out of the thermo roll is based on sliding pad that is held in contact with the measured roll.

Tapio-analyser was used for the measurement of the paper quality. Paper surface profile variation caused by the once per revolution roll deviation (1st harmonic component) has relatively long wave length. Depending on the roll diameter wave length is normally from 2...5 m. In regular printing products such a long term variation rarely causes visible defects whereas variations caused by short term geometrical errors on roll surface cause more easily optical variations that are noticeable by human eye [2].

In simplified form the model of the nip load in a calender can be described as equation of motion

$$F(t) = M\ddot{x}(t) + C\dot{x}(t) + Kx(t) \qquad (1)$$

where F is force caused by the system, x is displacement, $\dot{x}$ is velocity, $\ddot{x}$ is acceleration, M is vibrating mass, C is damping factor and K is spring constant. Although short term geometrical errors on roll surface cause only minor displacement (run-out) whereas acceleration can be high. It can be seen from the equation (1) that high acceleration gives high forces which means strongly oscillating nip pressure.

As result it can be stated that nip pressure variation caused by the run-out of the measured thermo roll clearly correlates with the paper quality variation.

2. METHODS

2.1 Calender under study

The thermo roll studied was mounted in a two-stack multi nip calender. Fig. 1 shows the calender concept. It consist of four thermo rolls (2, 4, 7 and 9), four soft covered deflection compensated rolls (1, 5, 6 and 10) and two soft covered intermediate rolls (3 and 8). Thermo rolls are arranged so that the first calender stack effects on the one side of the paper and second calender to the other side.

Cast iron thermo rolls had 32 peripherally drilled heating fluid channels. The flow of the fluid was designed as duo-pass. Temperature of the heating fluid inlet was 257 ºC and outlet 249 ºC.

Run-out measurements were done for the thermo roll number 7. Paper web speed was 1225 m/min and diameter of the thermo roll was 813 mm which equals 8 Hz as a rotational frequency. Line load used in nip was 165 kN/m.

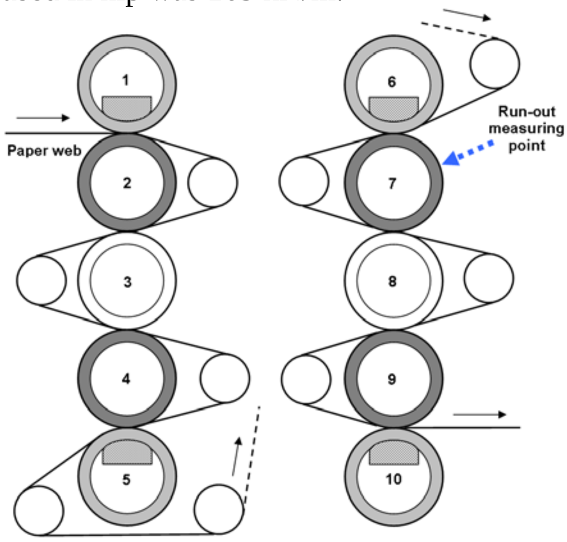

Fig.1. Layout of the multinip calender.

2.2 Run-out measurement of a calender roll

The slide pad run-out measurement method is based on the measurement of radial acceleration of the target surface. In this method, an acceleration sensor attached to a sliding probe is held against the rotating roll surface. The device consists of a polymer based, wear and heat resistant slide pad which is in contact with the moving surface, an accelerometer attached to the slide pad and an extension handle for the user to hold the device on the target surface. Once per revolution trigger signal, for example a photoelectric sensor, is needed for the synchronized averaging of the signal. Acquired acceleration signal is averaged and double integrated by a computer to get the surface displacement, i.e., run-out. The combined standard uncertainty of the method for the rotation frequencies typical with the paper machine rolls, that is from 5 Hz up, is 3 % (k=2). The method in question is discussed in detail in reference [3].

2.3 Off-line measurement of paper properties

Tapio Paper Machine Analyser (PMA) (Fig. 2) is widely used off-line paper sample measuring device that can be used in both MD (machine direction) and CD (cross direction). References [4], [5] and [6] give a comprehensive over view about the technical details of this measuring device.

Fig. 2. TAPIO Paper Machine Analyser (PMA). [6]

A 250 mm wide sample is cut from the produced paper and fed through the analyser. The measured data are analysed by the WinTAPIO software.

As discussed in [4] the sample step has a great influence on the data in terms of getting correct results. In this case a 12.8 mm sample step was used to achieve good resolution of the data. In this particular case analysis of the measured data was carried out by using the WinTAPIO but also self-made Matlab applications.

3. RESULTS

3.1. Thermo roll run-out

Thermo roll run-out was measured in normal process conditions. In Fig. 3 acceleration response of the sliding devise is presented in time domain.

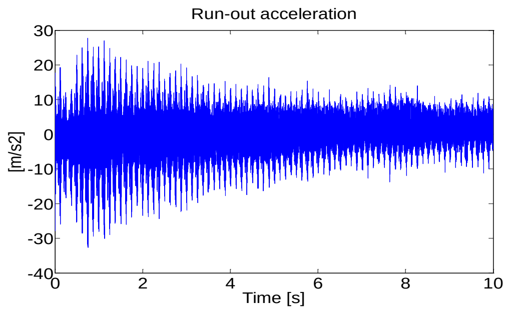

Fig. 3. Acceleration signal of a 10 second measuring period.

Fig. 4 shows acceleration, velocity and displacement spectra of the run-out. In acceleration spectra as marked by the dots there are two clearly distinguishable peaks, one at 8 Hz and the other at 256 Hz. Peak at 8 Hz is the 1st harmonic component of the measured roll run-out. Peak at 256 Hz is synchronous to the 32nd harmonic component of the roll rotation frequency. In velocity spectrum the peak at 256 Hz is much lower and in displacement spectra it is hardly noticeable.

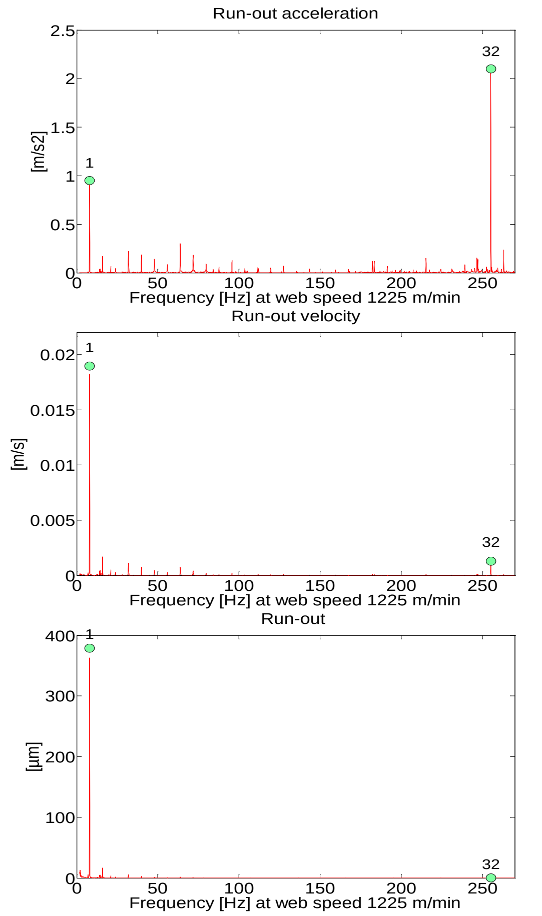

Fig. 4. Acceleration, velocity and displacement spectra of the roll surface run-out.

Fig. 5 shows the zoomed displacement spectrum of a frequencies around 256 Hz (32nd harmonic component).

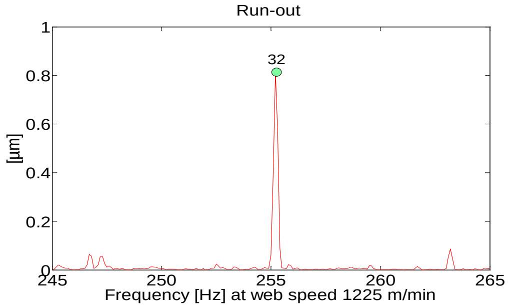

Fig. 5. Zoomed run-out displacement spectrum of the roll surface around 256 Hz (32nd).

In Fig. 6 are presented acceleration, velocity and displacement of one revolution of the 1st and the 32nd harmonic components.

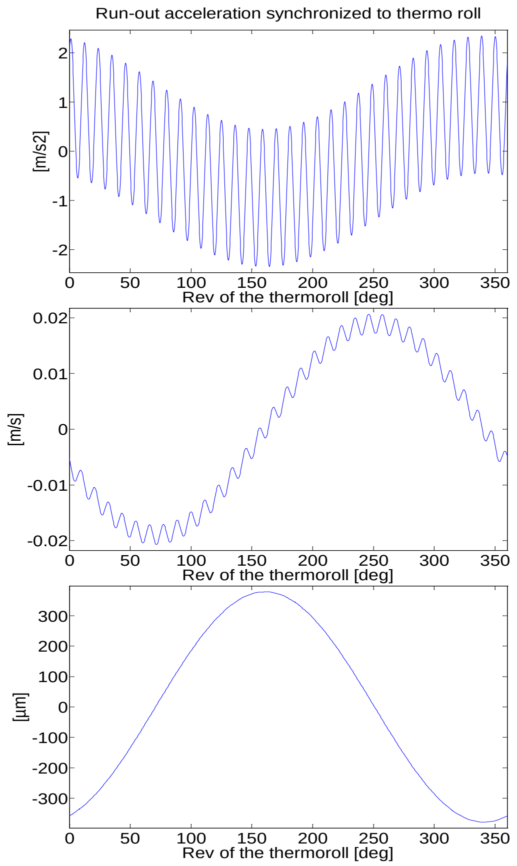

Fig. 6. Run-out acceleration, velocity and displacement generated by the 1st and the 32nd harmonic components.

3.2. Paper sample analysis

Paper sample in machine direction was taken in the middle of the web. The sample length was 4998 m. Sample reel was measured in the laboratory of the paper manufacturer by Tapio (PMA). In this case caliper and gloss variation were measured.

Caliper of the paper

In Fig. 7 is the caliper variation of the paper sample. The average of the paper caliper was 50.34 μm. The sample has a discontinuity at 2800 m but closer examination showed that it had no effect on the variables under study.

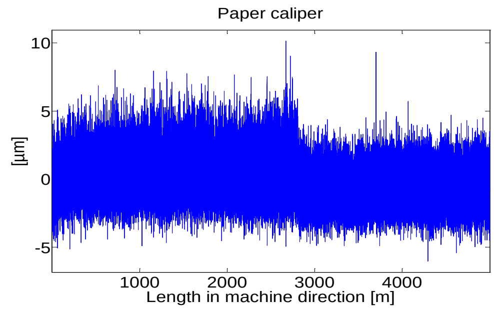

Fig. 7. Caliper profile of 4998 m long paper sample.

In caliper profile spectrum (Fig. 8) 1st harmonic component caused by thermo roll is distinctive. Also the 32nd component is notable.

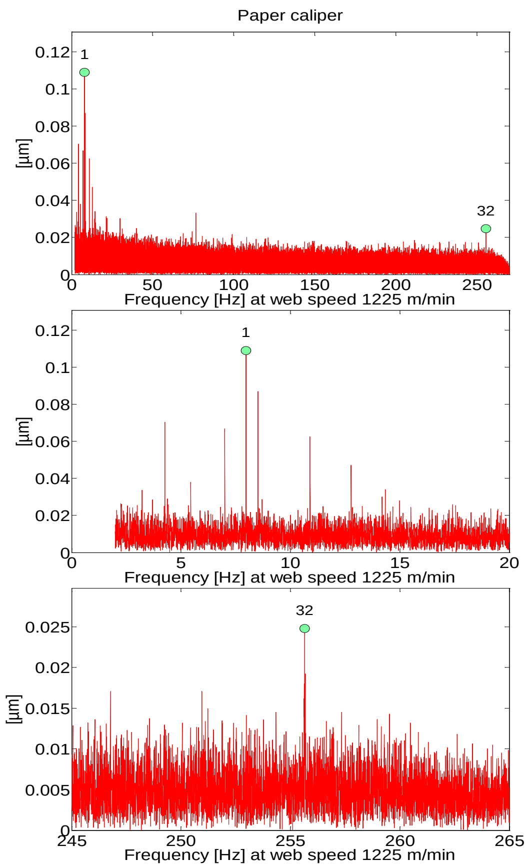

Fig. 8. Caliper profile in frequency domain. Zoomed figures shows the peaks of 1st and 32nd components.

Fig. 9 shows caliper variation during one thermo roll`s revolution of the 1st and the 32nd harmonic components.

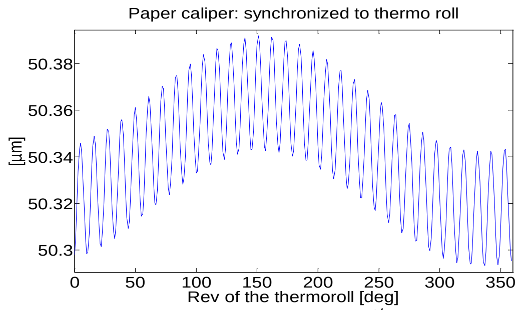

Fig. 9. Paper thickness of 1st and the 32nd harmonic components from one revolution of the thermo roll.

Gloss of the paper

In Fig. 10 the gloss variation of the paper side that is effected by the thermo roll is shown in time domain. The average of the gloss in paper sample was 46.49 %.

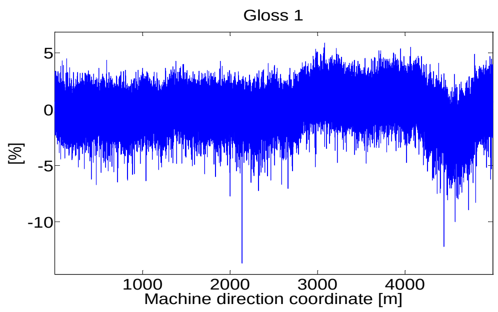

Fig. 10. Gloss profile of 4998 m long paper sample.

In Fig. 11 gloss spectrum of the paper sample is shown. The peaks of the 1st and the 32nd harmonic components differ from the spectrum. It can be stated that there are several peaks caused by other rolls around rotational frequency (1st component).

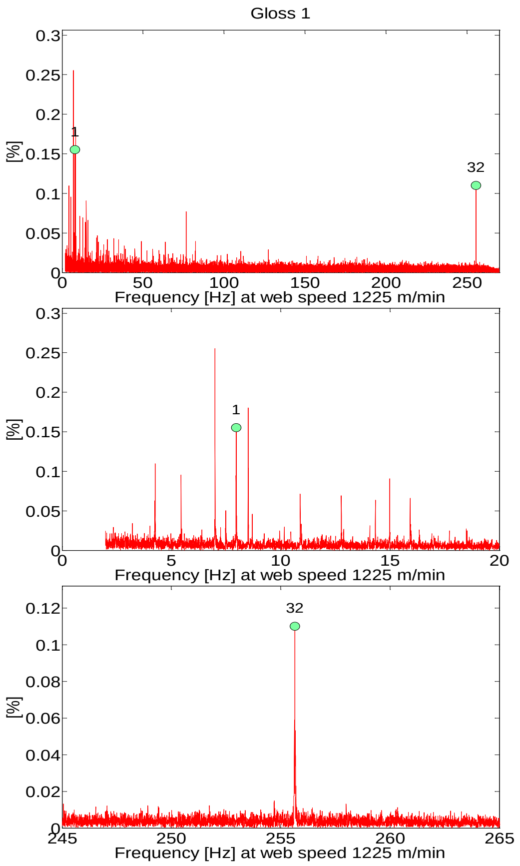

Fig. 11. Gloss variation spectrum of the paper sample.

Fig. 12 shows the 1st and the 32nd harmonic components of the gloss variation of one revolution.

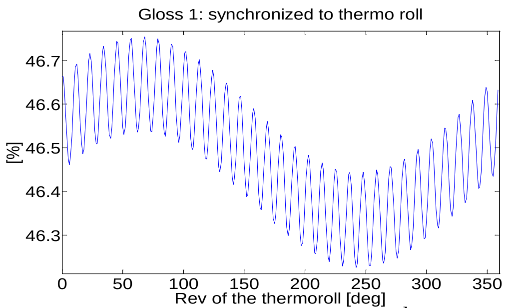

Fig. 12. The 1st and the 32nd harmonic components of the paper gloss of one revolution.

4. DISCUSSION

Results of the run-out measurements clearly showed that thermo roll had significant 1st harmonic component caused by thermal bending. As the run-out amplitude of the 1st component was 386 µm. In paper analysis this 1st component caused 0.11 µm caliper variation. 32nd component of the run-out was 0.8 µm whereas caliper variation in the paper sample was 0.025 µm.

It can be seen that deviation that occurs in higher frequencies in the thermo roll causes relatively greater deviation to the paper. The same phenomenon can be seen on gloss variation. This can be explained by the greater force caused by higher acceleration.

Case measurements showed that even minor deviation on roll surface can be detected in both run-out measurements but also as paper quality variation.

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CORRESPONDING ADDRESS

M.Sc. (Tech.) Jukka Pirttiniemi
Aalto University School of Science and Technology
Department of Engineering Design and Production
Sähkömiehentie 4P, P.O.Box 14400
FI-00076 AALTO
Phone: +358-9-47023546
Email: Jukka.Pirttiniemi@tkk.fi