Analysing Printing Press Runnability by Data Mining

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Abstract: Demand for better productivity of printing presses is one of the key topics in the publication industry. For a papermaker, this means increased demands for improved runnability of paper. Lots of measuring data is used for controlling the press but unfortunately this data is not normally stored for later usage. Paper mills do a huge amount of on-line and off-line measurements, which are normally used internally.

In this study, a large amount of diversified printing press and paper mill measurements were collected and a database was created. The aim was to clarify the reasons for runnability problems occurring in the pressroom. Over 2000 customer reels were measured at a newspaper press.

The software package created for data mining is introduced. Results from a long-term study, and the causes for runnability problems in the printing press, are presented in this paper.

1. Introduction

Increasing productivity is one of the key issues among printers and paper makers. The improved efficiency of presses is limited because of runnability problems occurring in the press. Typical runnability disturbances in presses include: web breaks, web instability, register errors and wrinkling.

The interaction mechanisms of paper web and press and the most important parameters affecting press runnability are inadequately studied. This is partly due the often insufficient instrumentation in the printing presses and the coincidental nature of the runnability problems.

The paper manufacturing and printing process produces a huge amount of measurement data, which is utilised insufficiently at present. Certain measurements are normally carried out in several places to ensure smooth

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production on the spot. By using advanced data management methods, such as data mining, it is possible, however, to combine the data measured in printing presses and in paper mills. This will help to find and optimise the key parameters of paper and printing press, which has a crucial impact on runnability.

In this study, data from paper mills and printing press databases were gathered. Different parameters were calculated for customer reels from paper mill measurements. The printing press measurements were a time series type of data, which was pre-processed for every customer reel. These data sets were combined and a new database including more than 2000 customer reels was created. The study was carried out by VTT in co-operation with newsprint producers and a newspaper printer.

The task of this work was to find methods and create a data mining environment to statistically analyse the runnability of the paper web in the printing press. Another task was to find the reasons behind the runnability problems in the studied press. These problems were occasionally found to be a slack web after the printing units, register errors caused by fan-out phenomenon and the lateral displacement of the paper web along the press. Especially one particular web caused these troubles and this printing tower was instrumented. Web breaks were not studied because only one tower was instrumented adequately and there were typically two to three webs printed simultaneously which were folded together. This meant that web breaks occurring in the folder area could not be included in the study and the amount of web breaks in the studied printing unit tower was not statistically sufficient.

2. Methods

2.1 Measurements

The printing press was instrumented with many additional measurements, which included web tension measured by weighing rollers in the infeed unit, after the printing units and before the folder in one printing tower. Other measurements included setting the values of infeed tension, driving rollers, folder controls and press speed.

The study was carried out in a coldset-offset newspaper printing press with a 4-high tower configuration. The measuring positions of some additional measurements can be seen in the Figure 1.

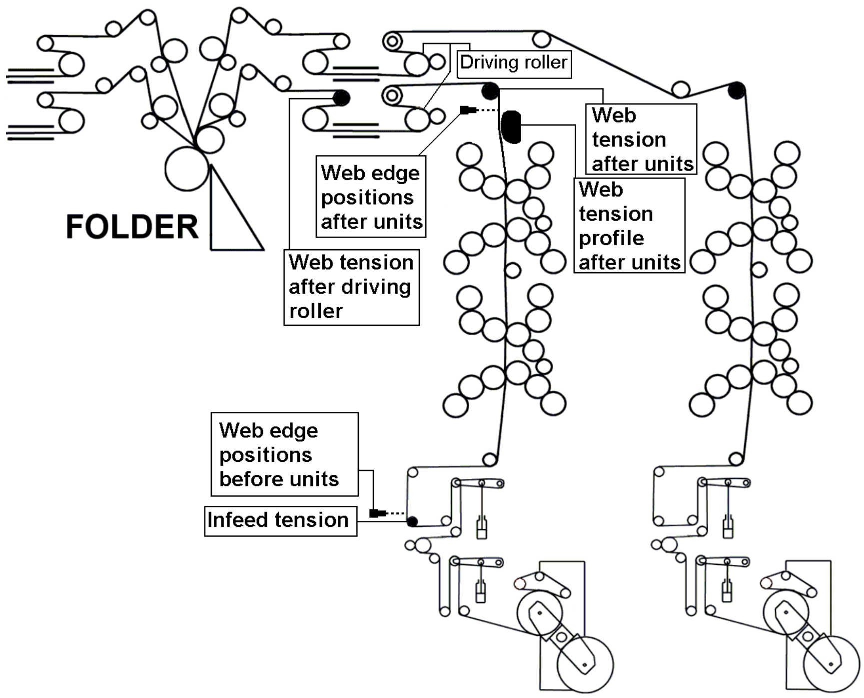

Figure 1. The positions of additional measuring points for web tension and web edge position in one 4-high printing tower.

The paper mill data included the following measurements: moisture, grammage, thickness, tensile strength, tensile strain, tear strength, reel position and reel density. One paper mill also supplied measurements of paper roughness and tensile stiffness orientation. The values for customer reels were calculated from the mean cross-machine profiles of the machine reels with the help of reel maps from the winders. Different sets in the winder could not be separated, since only the mean profiles were stored and laboratory measurements were carried out from paper samples from the top of the machine reel.

During the study, some special measurements were installed into one printing tower, which was already the most heavily instrumented. A new on-line version of cross directional tension profile measurement (IQTension) was installed after the printing units (Parola, 2000a, Linna, 2001). The basic idea of the measurements is to measure the pressure of the air film between a curved surface and the web. A beam with a curved surface deflects the web (Figure 2a). When the web speed is high enough, an air film is formed between the surface and the web. The distance between each value on the tension profile is 30 mm.

The web width and lateral movements were measured by line scan cameras (Figure 2b). Cameras were positioned on the web edges before and after the printing unit (Figure 1). These measurements are described in a detailed manner in the literature (Parola, 2000b).

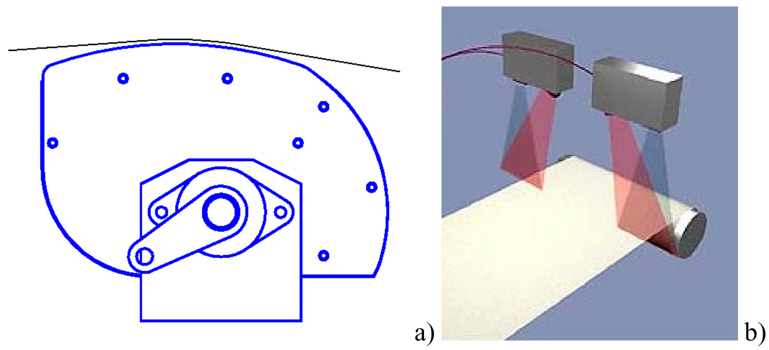

Figure 2. a) A side-view figure of the printing press version of IQTension. b) The method for measuring the positions of web edges by line scan cameras (Visi 10).

2.2. Pre-processing and database

The press measurement data was stored in the press and sent on a daily basis to an ftp-server. From there it was transferred, evaluated, pre-processed and combined in the database used for the study. The paper measurements were received from paper mills. A block diagram of the data flow is presented in Figure 3. About 2000 customer reels were analysed in the study.

In order to connect the measurements carried out in the printing press to the paper measurements, one reelstand was equipped with the barcode scanner. The reel numbers were read before the reels were placed on the reelstand. This information was stored in a log file.

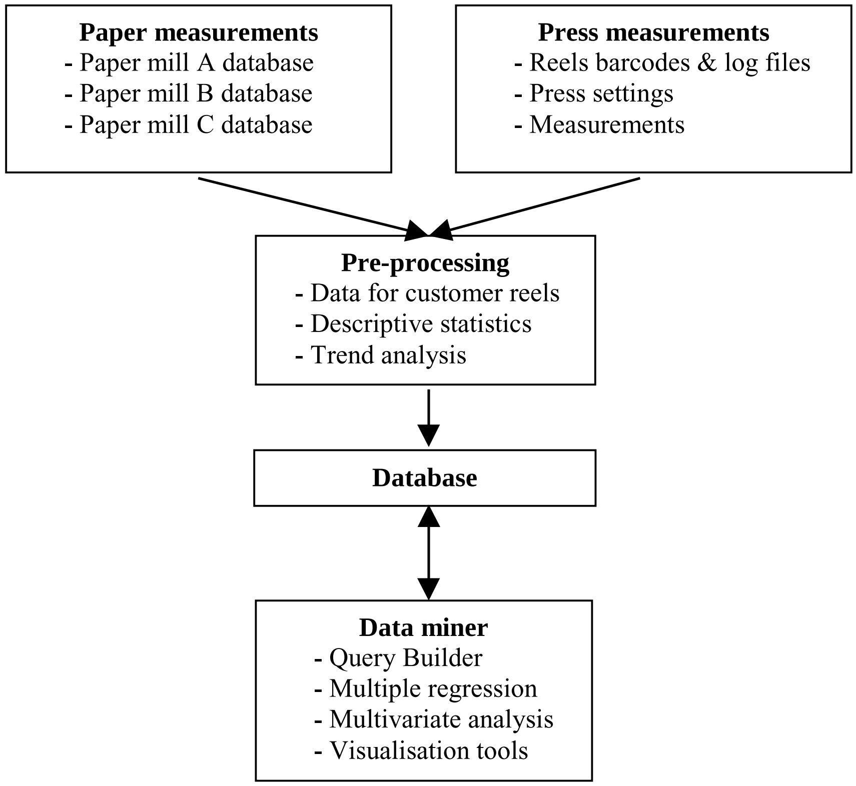

Figure 3. A block diagram of data flow.

The database was created so that all the measurement information from each customer reel was stored in one array. A Microsoft Access database was used.

The measurements in the press were mainly the time series type of data recorded by a frequency of 1 Hz. It was decided to store not the series themselves, but a set of the parameters calculated from the measurements (such as average value, minimum, maximum and trend). These parameters were calculated for an interval of time, during which the setting values of the press remain unchanged.

As an example, Figure 4 presents the results from measuring infeed tension and press speed for two hours while two customer reels (R1 and R2) were measured. For reel R2, the parameters are calculated for the entire interval of its printing, from the reel change moment t4 to t5; and for reel R1, the parameters are calculated for the time interval [t2, t3], since the speed of the press (dashed line) was increased at moment t2 (change time of reel R1 is t1).

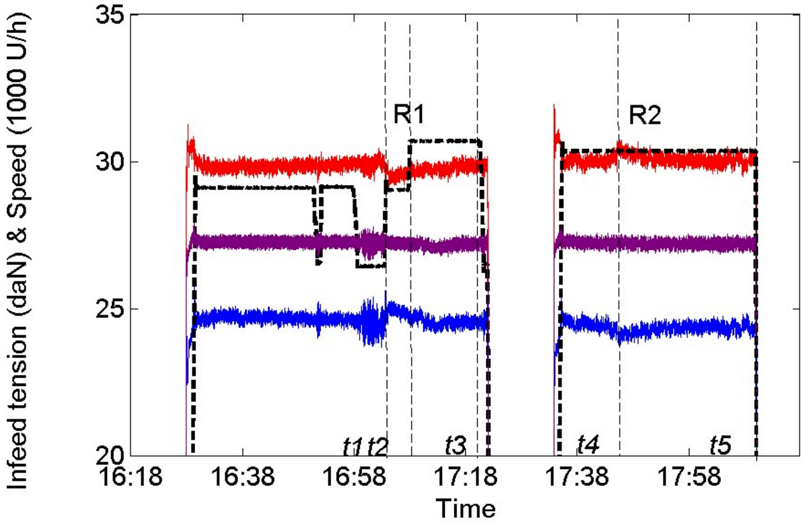

Figure 4. The time series for infeed tensions of the web measured at both edges, the mean value and the press speed (dashed line).

2.3 Analysing methods

An advanced interactive collection of programs was developed for the efficient mining of large data sets. The software was created using MATLAB (Martinez, 2002). The software includes programs for data reduction or sampling and prediction. Both classical statistical methods (Palm, 2001) and more computationally expensive recursive predictive methods are included. The methods used in the analysis are statistical methods such as Principal Components Analysis, modifications of Multiple Linear Regression, correlation analysis and a wide spectrum of different methods of data visualisation (Parola, 2003).

The Data miner allows to do queries from the database, which is an essential property. The data miner processes subsets from the database, which can then be analysed. One can, for example, sort out the data on the basis of grammage, setting values and so on. Figure 5 presents an example of a query in which all customer reels from mill A, which has moisture less or equal to 9.5 %, have been searched and it can be seen that 287 reels fulfil these conditions.

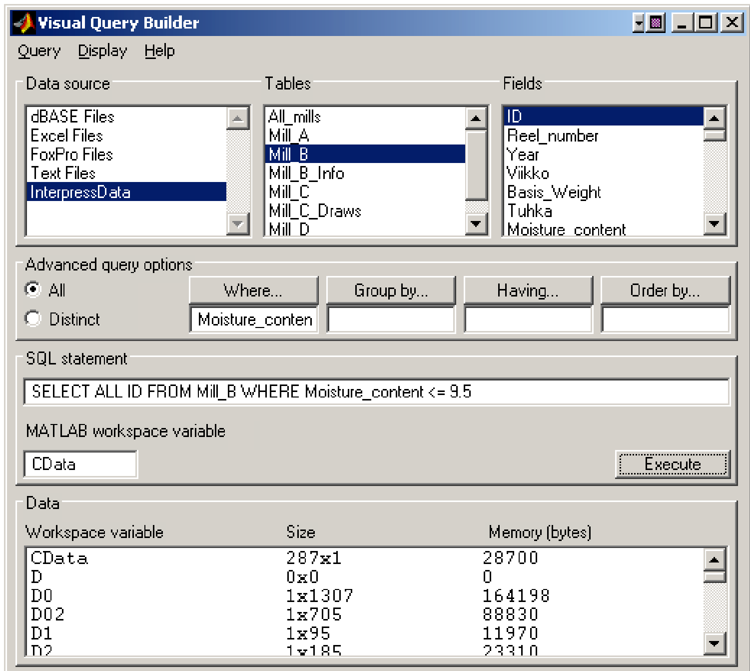

Figure 5. A work window for the MATLAB Query Builder.

3. Results

The main tasks were to create a data mining environment and find the crucial parameters affecting press runnability. The present runnability problems in the press were found to be the occasionally unstable slack web after the printing units and the register errors caused by web widening and lateral web movements. The slackness of the web complicates web management in the superstructure and folder. The problems connected to the slack web are presented in chapter 3.1, while the problems connected to register errors are presented in chapter 3.2 because these measurements begun in the latter half of the study and thus included less data.

3.1 Analysis of long-term data

The development work on the data-miner and data analysis was carried out simultaneously. In this way, the challenges of studying the paper-press interactions could best be met. Several functions of the created software described in chapter 2.3 were used in the analysis. The analysis work needed close co-operation with the printer and papermaker, as expertise in the examined processes is essential.

3.1.1 Press parameters

The slackness of the web after the printing units was analysed by studying the tension level after the printing units. This tension is important, as low tension, in other words slack web, causes web handling problems in the superstructure and folder. The effect of different press controls and parameters on the measured tension after the printing units was analysed with regression and correlation analysis. Figure 6 presents a regression modelling result for web tension after the printing units.

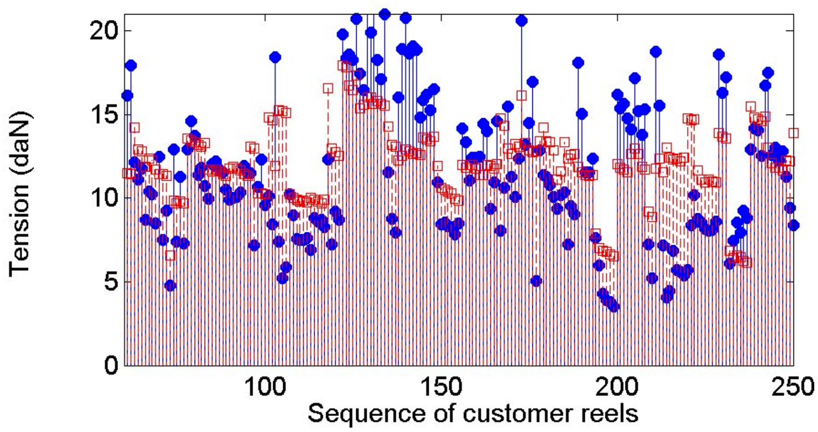

Figure 6. The regression modelling result for tension level after the printing units. Tension was modelled with infeed tension, driving roller setting, folder settings, press speed and by a time factor. The round markers represent the measured values and the square markers represent the values from the model.

It was found that large scale variations in tension level can be explained reasonably well by the chosen press characteristics. The most important factor found to have an effect on tension was the driving roller. This was a somewhat expected result, as the driving roller is very near the tension measuring point (see Figure 1). A tension increase in the reelstand also tightens up the web after the printing units. There are also many other parameters that have an influence on the examined tension that could not have been measured. These parameters include, for example, the amount of damping solution that has penetrated the paper, the nip load and the effect of the printing inks and blankets used.

Modelling helped to clarify the effect of different press parameters on web tension and to choose appropriate control strategies in the press.

The installed measurements and data mining software created made it possible to analyse the materials used in the press and carry out troubleshooting. It was found during the study that the back edge of the web was usually much tighter than the front edge after the printing units, which caused web instability in the superstructure. This tension variation across the paper web could be significantly diminished by changing some guiding rollers before the printing units. The effect can be seen in Figure 7.

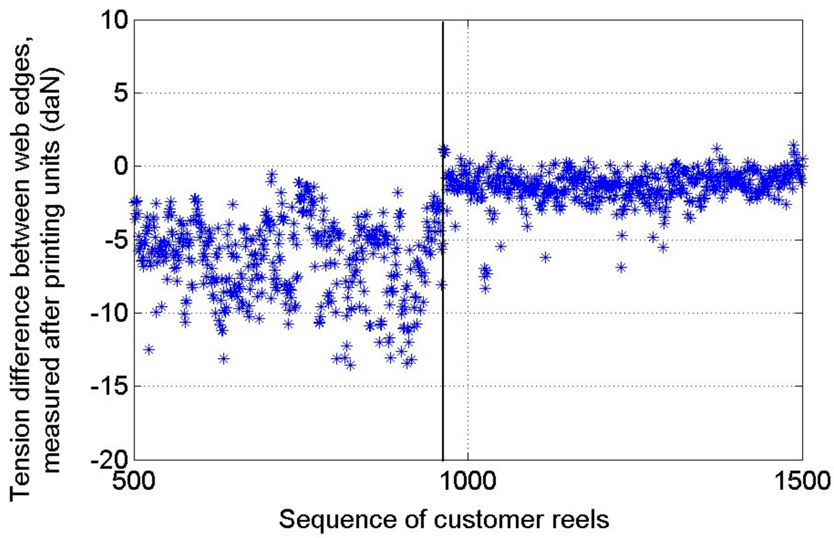

Figure 7. The effect of guiding roller change on the web tension difference between the web edges after the printing units. The moment of change is marked with the vertical line. The average value of tension after the units was 11.6 daN.

The rubber blankets may also cause changes in the runnability of the press. It was found that the worn out rubber blankets increased the cross directional tension variation.

The important press controls affecting tension after the units were discovered. This knowledge helped the printer to optimise control of the web through the press. Measurements and data mining also led to component changes in the pressroom, which helped the printer to achieve better runnability.

3.1.2 Paper properties

Paper measurements were carried out in three paper mills. The paper measurements are described in chapter 2.1. The papers were mainly used for different types of product and, for example, the grammage usually varied between different mills. This led us to subgroup the data by paper mill.

As can be seen in Figure 6, the press had a significant effect on tension level after the printing units. Due to this, the tension was first mathematically modelled by press characteristics. After this, the difference between the modelled tension values and the measured ones was studied to find out the possible effects of paper properties.

It was discovered that the position of the reel in tambour had an effect on the tension after the printing units (Figure 8). The reels cut from parent reel edges, the so-called 'edge reels', differ from middle positions.

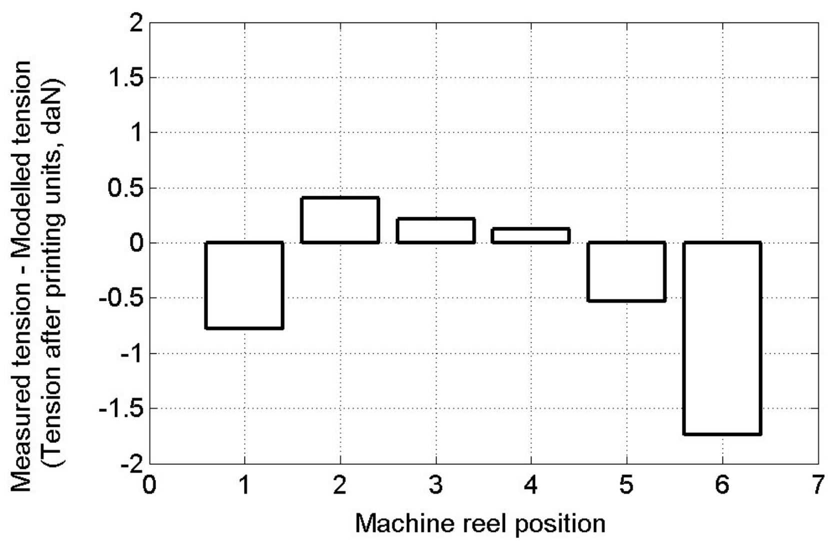

Figure 8. The effect of machine reel position on tension after the units. The tension modelled by press parameters is subtracted from the measured value (Y-axis). Reel positions 1 and 6 are edge reels. Some of the position 5 reels were also edge reels. Paper Mill A, 517 customer reels.

As the measured tension is lower than that predicted by the model, the outcome (Y-axis) is negative. This means that the edge reels gave a lower tension after the printing units than the middle position reels. It has been found in earlier studies (Linna, 2001) that the edges of the web in the paper machine differ from the middle areas in terms of web tension, tensile stiffness and drying shrinkage.

None of the other paper properties included in the study explained the slackness of the paper web after the printing units in the long-term study. However, the number of paper parameters included in the study was quite limited. It was also discovered that the tension level after the units varied from mill to mill. This suggests that, by extending the amount of paper parameters in the study, it would be possible to discover the key parameters. The interesting parameter discovered in this study is, for example, the furnish of paper.

In the near future, the printing house will install bar code readers to all printing units. This way the amount of information can be multiplied as reels can be identified. This also makes it possible to analyse the reasons behind web breaks and printed waste.

3.2. Results from new measurements

The measurements of web tension profiles, web widening and lateral movements began during the long-term study. These measurements are still going on and some preliminary results are presented here.

3.2.1 Web widening and lateral movements

Web widening was determined as the difference in the web width between the two measuring points (Figure 1). The web width and movements were measured from over 200 customer reels. The web normally widens as it goes through the printing units. The variation of this widening from reel to reel usually causes register problems, which are also called ‘fan-out’. This widening is partly caused by press components, such as printing nips, and partly by the hydroexpansion of the paper web (Tattari, 1998, Gomer, 1991). It was found that increasing the press speed decreased the amount of web widening, as suggested by the printer. It was also discovered that the increase in tension level in the infeed unit also led to an increase in widening. This result is contrary to results presented in the literature (Tattari, 1998) but the result was verified by the printer. The reason behind this phenomenon is yet unclear.

Printers experience has shown that if the web is tightened with the infeed unit to gain good runnability in the superstructure, then the printer is likely to face fan-out problems and has to find a balance between with these two different kinds of runnability problems and try to find the optimum tension level.

The effect of different paper properties on web widening was studied. It was found that the machine reel position had an effect on the widening; the edge reels had stronger widening than the middle position reels (Figure 9). This might be due to the known fact that the drying shrinkage of the paper is higher in the edge areas of the parent reel. In addition, an increase of roughness increased widening (Figure 10). The edge reels were excluded from this examination. Parallel results have been presented in (Tattari, 1998).

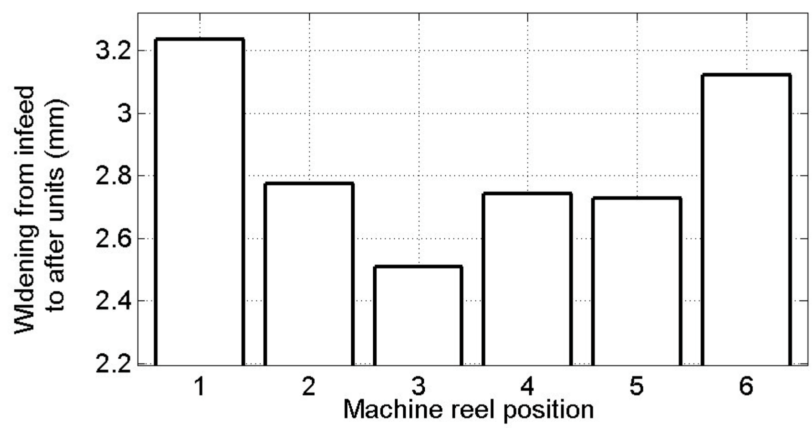

Figure 9. The effect of machine reel position on the web widening, Paper Mill A, 75 customer reels.

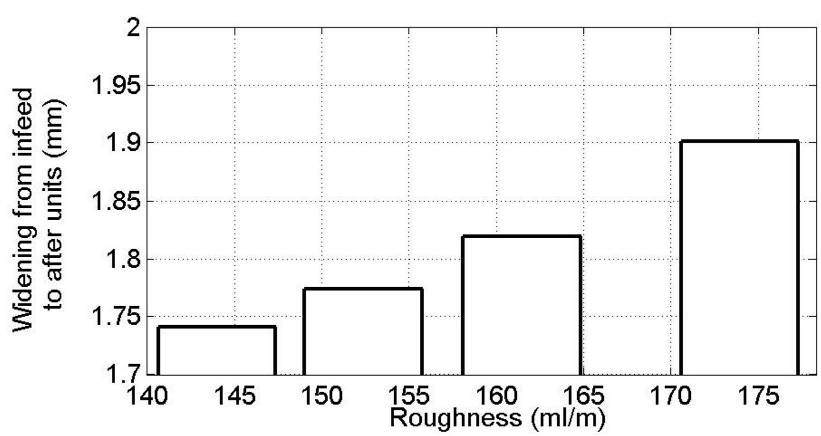

Figure 10. The effect of paper roughness on the web widening. Paper Mill C, 63 customer reels. The edge reels were excluded from the data set.

The lateral movements of the paper web were measured after the infeed unit and after the last printing nip. The movement was determined as the difference in web position between these two points. The lateral movement of the web causes register errors and, when serious, these may lead to a web break. It was found that the skewness of the web tension profile had an effect on the movements. The web wandered towards the tighter edge of the web. The movement caused by tension variation was between – 1 mm and + 1 mm, which is enough to cause severe register errors.

An estimate for fibre orientation was measured in one mill with a TSO-tester (Loewen, 2002). It was found that the tensile stiffness orientation angle (TSO angle) had an effect on web movements. In Figure 11, the lateral movement is plotted against the TSO angle value. The web tended to move in the opposite direction than that pointed to by the TSO angle. Similar results have been reported in pilot scale studies (Trollsås, 1998).

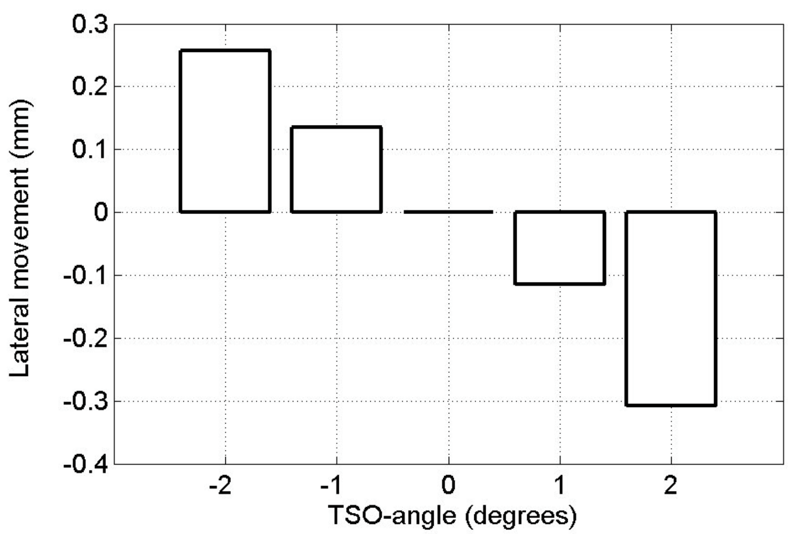

Figure 11. The effect of TSO-angle on the web movement, Paper Mill C, 106 customer reels.

3.2.2. Web tension profile measurements

An IQTension profile measurement system was installed after the last printing nip in one printing tower (see Figure 1). The profile has been measured from about 800 customer reels. Different parameters from these profiles were calculated, such as the skewness of the profile and the mean values for different pages. This analysis is reported later. Figure 12 presents the variation of web tension profile during one work.

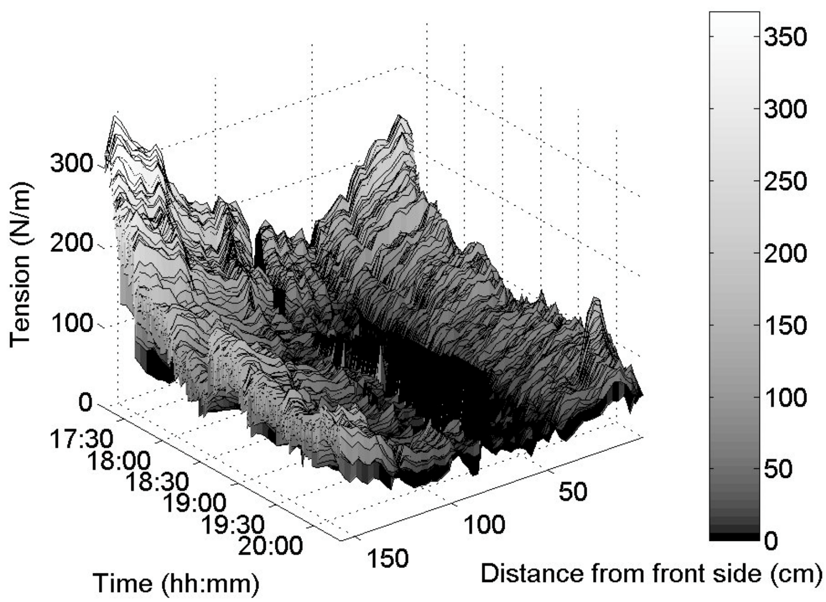

Figure 12. The tension profile measured after the printing units during one work.

It can be seen that the tension level drops during the work and that the shape of the profile is more or less concave.

The printer has found the IQTension measurement highly useful. With this measurement system, the printer is able to carry out troubleshooting, as well as to monitor the production. The measurement can also be used to evaluate the functioning of different materials. For example, the effect of different blankets or paper grades on the tension profiles, and further on to the runnability of the press, can be examined in detail.

4. Conclusions

There is an increasing demand for better productivity in printing presses. This means that the utilisation rate of presses has to be improved by solving runnability problems. These problems include web breaks, web instability and quality failures such as register errors that lead to an increasing amount of paper waste. Presses normally use several paper grades from different paper mills and therefore the interaction of the press and the paper web is highly important for the printer as well as for the paper maker.

The paper manufacturing and printing process produces a huge amount of measuring data, which is utilised insufficiently at present. By collecting and refining these measurements it is possible for the printer to make the production more effective. The paper maker could also benefit from this kind of close co-operation; the important parameters affecting the pressroom runnability could be identified, which would lead to better paper quality through development work.

Because there are many parameters in the press, which has an effect on the paper web behaviour, the short test runs often leave many unanswered questions. This is one of the most important reasons why data mining was applied to study runnability problems. The task of this work was to find methods and create a data mining environment to statistically analyse the runnability of the paper web in a coldset-offset printing press. Another task was to find the reasons behind the runnability problems in the studied press. These problems were occasionally slack web after the printing units, register errors caused by web widening and lateral displacement of the paper web along the press. Over 2000 customer reels were measured in the press. The paper measurements were carried out in the paper mills.

It was found that the press components had a major impact on the slackening of the web. In addition, the paper had an effect; the edge reels tend to slacken more than the middle position reels. Further studies are required to solve this problem. It was found that certain press components caused distortion in the web tension across the web. The problem was overcome by the corrections carried out. Further, worn rubber blankets caused skewness in tension.

New measurements installed in the press proved to be useful. Preliminary results suggest that both press components and paper properties have an effect on web widening, which causes register problems. The edge reels and higher roughness gave stronger widening. The web tension variation across the web led to lateral movement along the press. Papers TSO angle had an effect on movement as the more the TSO angle differed from zero, the more the web wandered sideways. The printer has found IQTension measurement useful in troubleshooting and material evaluation. The data collection is still going on and final results will be reported later.

The developed data mining tools and software were found to be invaluable for analysing the runnability problems in the press. Data mining helped the printer to monitor the production and solve problems that arise in the pressroom, which led to increased know-how among the staff. The important press controls affecting web slackening were discovered, which helped the printer to optimise the web control through the press. Measurements and data mining also led to component changes in the pressroom, which helped the printer to achieve better runnability.

Implementation of data mining method has many steps that must be performed successfully. The basis for data mining work lies in the strong commitment of different joining parties. The expertise of all parties must be available for every step of the work. The verification of the measurement data has to be done continuously and calibrations should be performed frequently. The measurements should include all the crucial parameters that can be measured.

In this study, one printing tower was instrumented. The installations in other printing towers and reelstands are going on. In the follow-up project, the measurements carried out in every printing tower are included in the study. This also enables analysis of the web breaks and paper waste. Additional paper properties will also be added to the data set. The data mining programs will be developed further. For example, new features, such as neural network, will be added to the data mining system. The time consuming pre-processing of the time series data will be automated.

Data mining gives an excellent tool for the printer and paper maker to find and verify important factors affecting the paper web's performance on the press.

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