

INFLUENCE OF KRAFT PAPER QUALITY ON THE PERFORMANCE OF AN INDUSTRIAL PAPER IMPREGNATION PROCESS

Manuel Facada

Universidade Técnica de Lisboa, 1049-001 Lisboa, Portugal

Abstract

At an industrial paper impregnation process a study was performed to assess the variability of one of its raw materials (Kraft paper) and its effect on the process performance. Therefore Kraft paper from two different suppliers was measured for different quality properties (porosity, thickness, density, moisture). It was observed that one of the paper suppliers when compared to the other provides paper which has higher density and lower thickness and porosity.

In a second stage, historical process data was analysed using multivariate data analysis techniques. It was found that the process has different performances according to the combination of the paper format and the different resin types. Evident correlations between two paper quality properties (porosity and moisture) and the process performance could be noticed. Based on the observed facts, adjustments to the paper specifications for porosity and moisture (applicable to both suppliers) are recommended. This can lead to an improved process performance, where a saving in the gas consumption up to 15% can be achieved, as well as an increase up to 5% in the output.

Keywords: Kraft paper, paper impregnation, MVDA, process knowledge and understanding, paper porosity

For confidentiality reasons, the names of the paper suppliers have been omitted, as well as process values, and the paper specifications have been normalised.

1. Introduction

In this project we aim to collect data and to assess the variability of Kraft paper and its effect on the process performance.

Kraft paper

Paper is a thin layer of mostly cellulosic plant fibres, produced on a screen by dewatering slurry of fibres in water. The slurry is called pulp. This pulp can be achieved by separating cellulose fibres from wood, fibres crops or waste paper.

To ensure that the different paper applications are successful, paper

characteristics must be controlled. These characteristics are strength, thickness, porosity and absorption, among others. Paper strength is obtained by using strong, long fibres pulp, and sometimes combined with a certain amount of shorter fibres for an improved structure and uniformity avoiding weak spots. Wet strength is increased by adding a wet strength chemical to the pulp. [1]

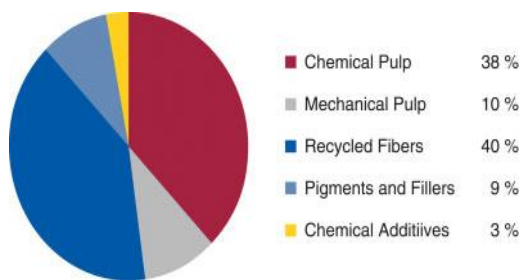


Figure 1. Components used in paper and board worldwide (mass percentages)

2. Data analysis

Kraft paper quality measurements univariate approach

The variability roll-to-roll and between suppliers is analysed, using univariate approaches.

Table 1. Kraft paper specifications per supplier.

Suppliers	Specifications	Density	Grammage	Porosity	Moisture
A	minimum	0	0	0	0
	maximum	1	1	1	1
	nominal	0,5	0,5	0,5	0,5
B	minimum	0	0	0	0
	maximum	1	1	1	1
	nominal	0,5	0,5	0,5	0,5

During the time line of this study 4105 rolls were processed by the impregnation line. From these 521 B rolls and 414 A rolls were analysed by the PPA, which represents 23 % of the total rolls.

The PPA measures grammage, thickness, porosity and moisture of the paper. A fifth property is density, which is not directly measured but calculated instead according to equation 3.

$$\text{Density} = \frac{\text{Grammage}}{\text{Thickness}} \quad (\text{g/m}^3) \quad \text{Eq. 1}$$

Each figure below illustrates the difference between each supplier and the off-specification measurements for each measured property.

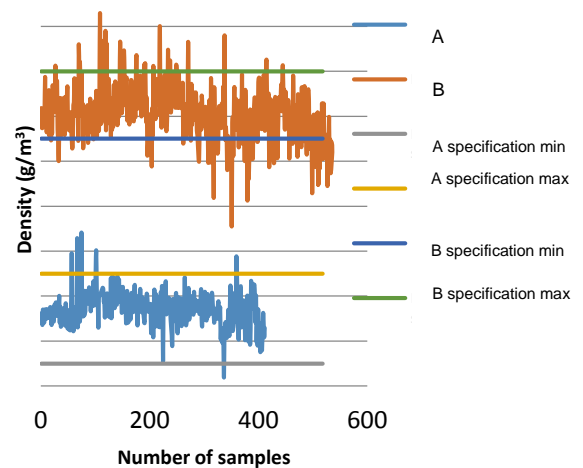


Figure 2. PPA density measurements on Kraft paper.

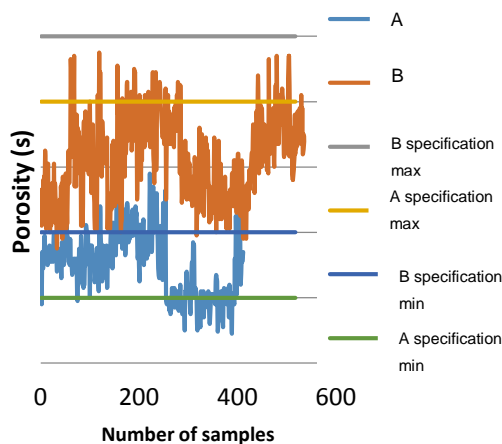


Figure 3. PPA porosity measurements on Kraft paper.

In total 25 % of A samples were out of specifications, being the porosity the main reason (ca. 17 %). For B in total 17 % of the samples were out of specifications being the main cause the grammage (ca. 8,3%). The differences observed between the two suppliers were already expected, as each supplier has a different Kraft paper production process and even uses different Kraft pulp as raw material.

The B compared to A has:

- Higher density;
- Lower thickness;
- Lower porosity (because porosity is measured according to Gurley, higher values for the measurement will correspond to lower porosity of the paper).

Kraft paper quality measurements: multivariate approach

Multivariate data analysis was applied to the quality measurements performed on the Kraft paper to assess the variability roll-to-roll and between the two suppliers. A

specific software was used for this analysis: SIMCA v.13 (MKS Umetrics, Umeå, Sweden).

The model explains 95% of the variance in the dataset in 3 principal components. The scores plot shows that the scores are clearly clustered according to the supplier. This is in accordance to what has been previously said in section, as each supplier produces paper with particular characteristics.

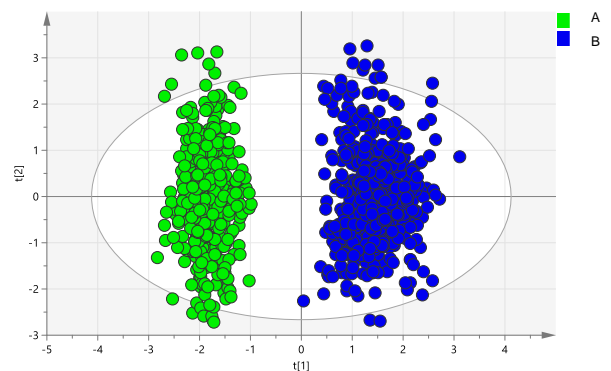


Figure 4. PCA to Kraft paper quality measurements: scores plot.

The loadings plot shows that porosity, thickness and density are the qualities that make the distinction between the suppliers so clear, confirming again what has been previously seen. The scattering in each cluster in the second principal component direction is due to variations in moisture and grammage: the higher the second principal component scores are the higher the values of moisture and grammage are. The higher the first principal component scores are the lower the thickness and the porosity (according to Gurley) are and the higher the density is.

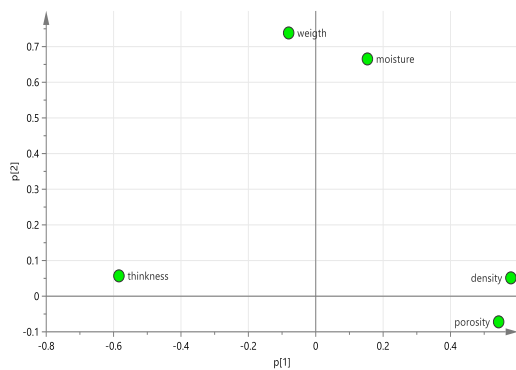


Figure 5. PCA to Kraft paper quality measurements: loadings plot.

Analysis to the impregnation process

In the historical data from the paper impregnation process there are 108 variables/parameters recorded. From these, the following are set at the beginning of the process:

- Line speed,
- Product format (paper sheets length),
- Ovens temperatures,
- Paper band tension,
- Amount of resin in the paper.

The most evident pattern in the process data is with the line speed. Also the resin type looks to have some influence on the process performance. The product format and the paper suppliers do not show a significant impact on the process, as the scores are mixed.

The resin types are already known to have impact in the impregnation process. Each resin has different line speed target, due to the different volatiles concentrations arising in the ovens. Each resin has different quantity of solvent used to adjust the

viscosity. In general, the more viscous the resin is the lower the solvent concentration in the resin (and consequently the lower the volatiles that arise in the ovens). The table below shows the viscosity of each resin.

Table 2. Viscosity ranges for the different resin types.

Resin Type	B13	B21	F30	F33
Viscosity	1	0,45	0,4	0

There are four sensors for volatiles concentration in the ovens, located at different places. Sensor number 3 placed in oven number 4 is the one reaching the highest values.

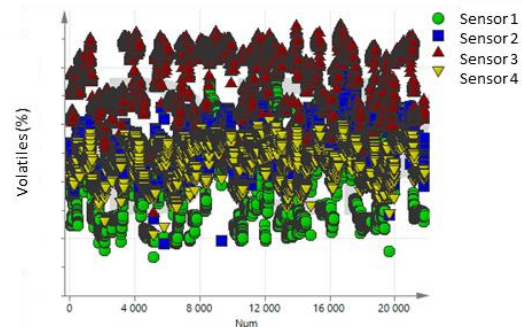


Figure 6. Volatiles concentrations in the ovens measured by the four sensors (1-4).

Because sensor 3 is the one reaching the highest values (close to the Low Explosive Level values), it is this one where the operators focus during the process.

As just seen, the performance of the paper impregnation process will be affected at least by the type of resin, the format of the paper and by the process parameters. After refining the datasets, another important correlation was found that was not evident

using all the process data at once. Depending on the line speed the gas consumption in the ovens is changing. This observation is expected, since the semi-finished needs to meet the specification for volatiles content. As the line speed increases the retention time of the paper in the ovens decrease and if the ovens temperatures do not increase, the volatiles in the semi-finished would increase and be out of spec. Therefore the temperature in the ovens need to be increased to keep the same volatiles release rate and keep constant the remaining content in the impregnated paper. As a consequence, the gas consumption increases due to the increased temperature.

Kraft paper quality and process performance: exploratory analysis

Only moisture and porosity was identified has critical properties on the process.

The theory says that a very dry paper will have a bad impregnation ability. Some moisture is needed as a drive to enable the resin to penetrate the paper pores by capillarity. [2]

The influence of the paper moisture can be seen on parameters/variables of the process, each resin and supplier has different impact on the impregnation line. It seems that the speed of the line tends to decrease with increasing paper moisture. As a consequence, the temperatures in the ovens are decreasing as well as the gas consumption with the decrease of the line speed.

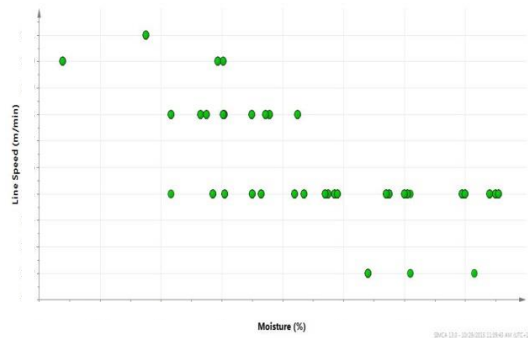


Figure 7. Influence of paper moisture on line speed Data referring to A paper in combination with IF format and resin B13

For paper supplied by B the situation is similar. The same type of trends is observed.

Regarding the volatiles concentration in the ovens, also an influence of the paper moisture is to be observed, but only for B paper, the higher the paper moisture, the higher the volatiles concentration. For A paper this effect was not observed.

For resin F30, in general the trends are the same as described for B13. However for resin F30 an additional impact of the paper moisture can be seen on the gap between the dosing cylinders. This is not visible for resin B13. This may be due to the resin properties, such as viscosity. B13 is less fluid than F30, which can have an impact on the amount of resin that adheres on the paper surface, dominating the paper moisture effect.

In general, the line speed and consequently the ovens temperature and the gas consumption decrease with the increase of the paper moisture. This can happen because the impregnation of the paper is so effective as the paper moisture increases that the volatiles content specification is exceeded as well as the volatiles content in the ovens reaches easily the Lower

Explosive Limit percentage. As a consequence the process has to slow down. Nevertheless, some deviations to this trend could be found for A paper and resin B13.

A and B have different ranges of porosity. The differences in porosity are related to the paper specific area. Theoretically higher porosity will lead to higher specific area, which facilitates the resin impregnation of the paper. [1]

Just like already observed for paper moisture, also paper porosity is influencing the line speed, and consequently the temperatures in the ovens and the gas consumption. As the paper porosity increases, the line speed decreases, as well as the ovens temperatures and the gas consumption with A.

B paper porosity will have almost no impact on the line speed, gas consumption and ovens temperatures, as well as on volatiles in the ovens. The situation observed for A, in which an increase of the paper porosity is leading to an excessive impregnation and a consecutive slow down of the process, seems not to occur for B. B paper is less porous than A, and therefore not so favorable to the resin impregnation for both resins.

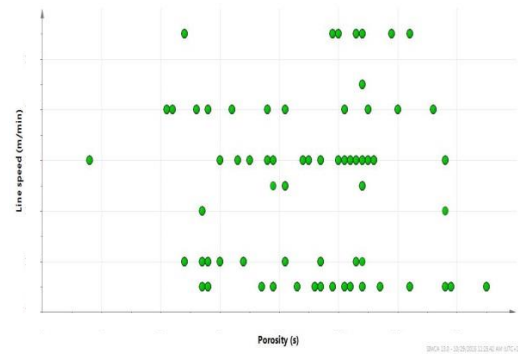


Figure 8. Impact of paper porosity on line speed. Data referring to B paper in combination with IF format and resin F30.

As already observed for the paper moisture, also the dosing cylinders gap has a correlation to the A paper porosity in combination with F30 resin. The lower the paper porosity, the lower the gap. However for resin B13 there is no evident impact from the paper porosity. This was also happening for the paper moisture. Apparently, the reason would be the same: B13 is much more viscous than F30 and the adherence of the resin onto the paper is dominating over the paper porosity effect.

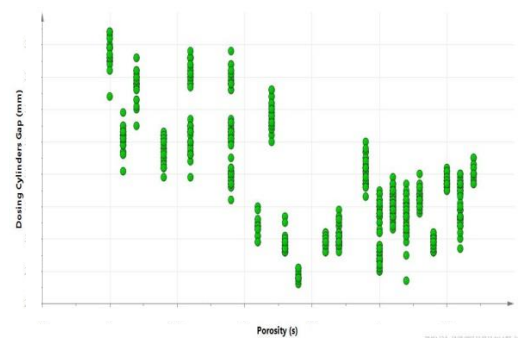


Figure 9. Impact of paper porosity on the gap between the dosing cylinders. Data referring to A paper in combination with SF format and resin F30.

Impact of critical Kraft paper properties on key process performance indicators

The impact of the critical paper properties, moisture and porosity, was quantified for two important process performance indicators, the line speed and the gas consumption. The first is related to the process output (amount of semi-finished produced per time unit) and the second is related to energy consumption. This was done by calculating per batch the average line speed and gas consumption and then plotting against the paper properties of the roll used for that batch.

For resin B13 and A paper, the output can be increased until 5% (above the target line speed) by keeping the moisture and the porosity on the low level. This is also beneficial for the gas consumption.

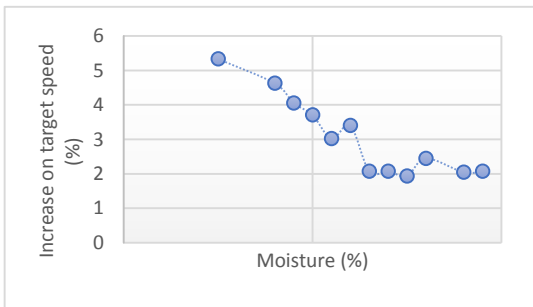


Figure 10. Impact of the paper moisture on the line speed. Data is referring to A paper in combination with IF format and resin B13. Plot based on 35 paper rolls.

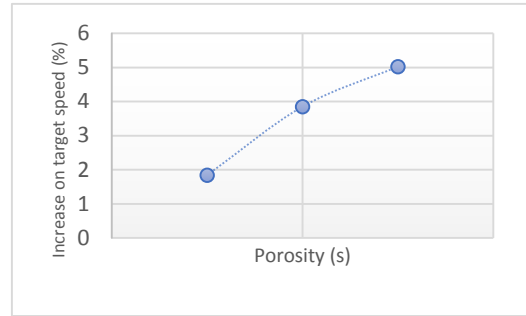


Figure 11. Impact of the paper porosity on the line speed. Data is referring to A paper in combination with IF format and resin B13. Plot based on 35 paper rolls.

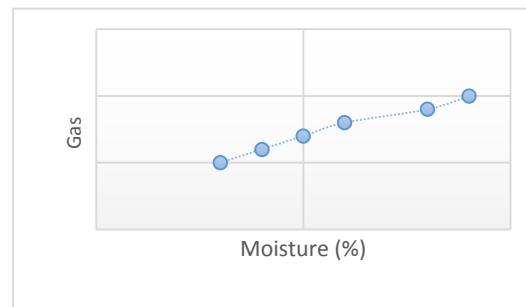


Figure 12. Impact of the paper moisture on gas consumption. Data is referring to B paper in combination with IF format and resin B13. Plot based on 28 paper rolls; Fixed Line speed.

For resin B13 in combination with B paper, the best results for the gas consumption are achieved when the paper has lower moisture and porosity.

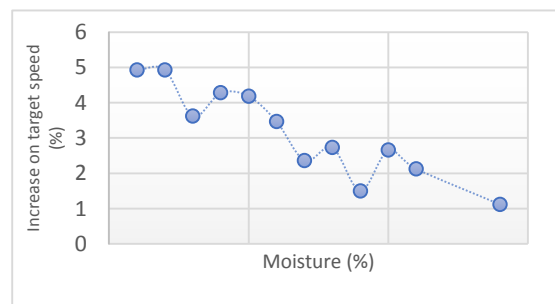


Figure 13. Impact of the paper moisture on the gas consumption. Data is referring to A paper in combination with IF.

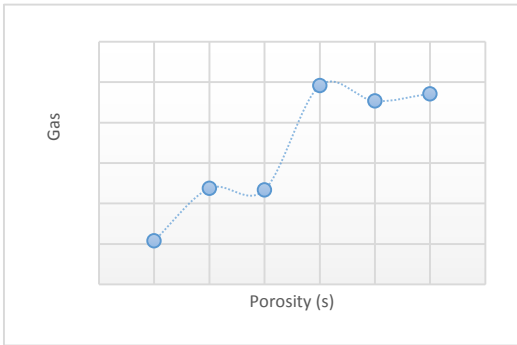


Figure 14. Impact of the paper porosity on gas consumption. Data is referring to B paper in combination with IF format and resin B13. Plot based on 28 paper rolls; Fixed line speed.

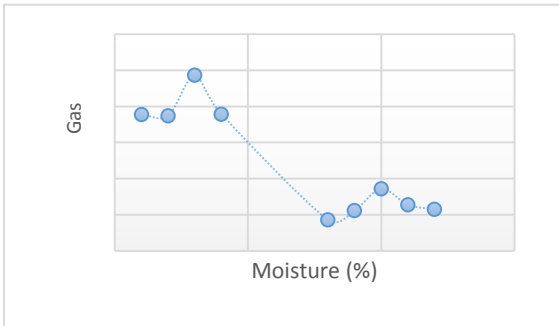


Figure 15. Impact of the paper moisture on gas consumption. Data is referring to B paper in combination with IF format and resin B13. Plot based on 28 paper rolls; Fixed Line speed.

For resin F30 the same is observed. By keeping the paper moisture and porosity on the lower level, increases in the output together with less gas consumption can be achieved, no matter which paper supplier is used.

Proposal for adjustments in the Kraft paper specifications

By monitoring the paper critical properties and reacting accordingly, two key process performance indicators can be improved, i.e. output and gas consumption. No extra investments in equipment are needed.

Eventually a different way on how raw material inspection is done would have to be adopted. Currently the paper rolls are checked just before being used. That does not allow enough reaction time in case some critical property is out of spec.

The following tables give an indication of the potential increase in the selected key process performance indicators (it is a comparison between the worst case scenario and the best one). Only data for line speeds equal or higher than the target was considered and the results were averaged for all formats. In total the data contained 116 rolls of B paper with resin F30 and 128 with B13, and 97 rolls of A with resin B13 and 67 with F30. If the paper control is applied and only A paper with porosity ranging from 0,35 to 0,56 is used, the potential increase in the process output can be as shown in the table below.

Table 3. Example of the increase in output by controlling A paper porosity (worst case: porosity is 0,35).

	B13		F30	
Porosity	0,42	0,56	0,42	0,56
Output increase (%)	1,3	3,6	1,7	2,9
Rejects (%)	4,0		6,1	

For A paper an increase of ca. 4% in the output can be achieved by optimising the porosity, and a maximum of 6% of rolls will be outside this new specification range. For B paper, the rolls that are not optimal in porosity for one resin type can be used for the other type.

Table 4. Example of the increase in output by controlling B Kraft paper porosity. (worst cases: for resin B13 - porosity is 1 ; for resin F30 - porosity is 0,56).

	B13		F30	
Porosity	0,56	0,7	0,7	0,91
Output increase (%)	1,4	1,1	2,9	3,3
Rejects (%)		3,9		

Table 5. Example of the increase in output by controlling Kraft paper moisture.

	A+ resin B13		B + resin F30	
Moisture	0	0,6	0	0,6
Output increase (%)	5,3	1,8	4,8	2,5
Rejects (%)	4,1		2,1	

3. Conclusions

The main objective of this thesis was to access the variability of one of the raw materials of an industrial paper impregnation process, i.e. the Kraft paper, and find out if the quality variations would affect the process performance.

The Kraft paper is supplied by two different paper manufacturers, A and B. It was observed that paper delivered by B has higher density and lower thickness and porosity, compared to A paper. The variability found in the paper quality measurements is responsible for 25% of the A rolls to be out of specification (mainly related to porosity variations), where as for B only 17% fail the specification (mainly due to grammage variations).

The process performance was analysed with multivariate data analysis and it could be seen that two major factor are dominating: paper format and resin type. Only by isolating these factors the influence of the paper quality on the process performance could be seen and two critical quality properties of the paper identified: moisture and porosity. These have a significant impact on the ability of the paper to get impregnated with resin. In general the best performance of the process can be achieved as the paper has lower moisture content and porosity. The process performance was evaluated by selecting two key process performance indicators:

output and gas consumption. The first should be maximised and the second minimised.

Based on the found correlations between the paper properties and the process performance, a proposal to adjust the current specifications for paper moisture and porosity was presented. Depending on the paper supplier and the resin type, an increase of up to 5% in the output and a decrease of up to 15% in the gas consumption can be achieved if the supplied paper falls into the new specifications.

4. Future work

The schedule of this study was very tight. Only data from 3 months was analysed. During this time it was not possible to gather enough data regarding two of the four resin types (B21 and F33), as well as the third paper supplier (C). A complete study would need to include this missing information as well.

The impact of the resin quality variations has never been so far quantified. It is known from a qualitative perspective that the performance of the process is dominated by the resin type, but within each type the impact of the variations remains unknown.

The suggested changes in the specifications ranges need to be discussed with the paper manufacturers, first to evaluate their capability in supplying the paper according to the new ranges and second to verify if that would have an

impact on the costs. Afterwards, the logistics around the paper delivery and quality inspection would have to be modified. The paper rolls would have to be inspected right after delivery in order to assure that only material within the new specification ranges is used in the most optimal way (i.e. in combination with the favourable resin type). This may request extra resources, such as operators, time and eventually storage room.

References

[1] Holik, H. (2006). *Handbook of Paper and Board*. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.

[2] <http://www.paperonweb.com/paperpro.htm> (consulted in 25/09/2015).