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IMAGING IN DISTURBANCE ANALYSIS OF SECOND STAGE PULP REFINING

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Abstract – This paper gives an introduction to the imaging in process analysis. The analysed process, where the images are taken from, is the second stage pulp refining process in TMP-plant. Either the images or the analysed features of the images are compared with the process data. The obtained results show that changes in process variables have effect on the images.

Keywords: Imaging, pulp refining, TMP

1. INTRODUCTION

Refining process has a very important role in the paper industry. One reason is that the refining process consumes a huge part of the total energy and other reason is that the refined pulp has an effect on the paper quality. Pulp with good and steady quality with lower energy consumption is wanted, but the disturbances in refining process have a negative effect on both variables.

Two phase refining process consists several lines. One line has wood chip processing machinery, two refiners, feeding screws, two cyclones and a blow line. In the process, a feeding screw feeds the washed wood chips into the first phase refiner. After the refining the generated pulp is in a mixture of pulp and saturated steam. Due to the pressure difference, this mixture flows through the blow line into the cyclone where the steam is separated from the pulp. After the separation, another feeding screw feeds the pulp into the second stage refiner for the second refining. After the refining process the produced pulp goes to the screening.

In this study, imaging is used to search reasons for disturbances in the second stage refining process. The conditions in the process were difficult, for example process temperature is over 150 °C and the moisture is high. Regardless of these difficulties, three different process line positions were used in the installation of the CCD camera; the blow line, the cyclone and the casing of the second stage refiner.

Simultaneously with the taken images, process data and synchronization pulses from the camera were logged. These synchronization pulses of each image made possible to find an exact place for images in the time base and therefore they could be compared with the process data. However, not only images themselves were used in comparison, some calculated features of the images were also used.

2. IMAGING AND DATA GATHERING

By using two different objective lenses, Cosmicar 12 mm and Moritex 17 mm, images were taken in sets of 300 – 500 images (total amount more than 50000) at the frequencies of 12,5 and 25 Hz (mostly at the frequency of 12,5 Hz). Images were taken through windowed flanges, which were attached in three different positions; in the wall of the blow line, on the top of the cyclone and in the wall of the refiner casing. In the first case, a stroboscope, which was the light source, and the camera were in the opposite sides of the blow line wall. In the last two cases stroboscope was attached behind the camera. The part of the refining process and the used installation positions of the camera are presented in Fig. 1.

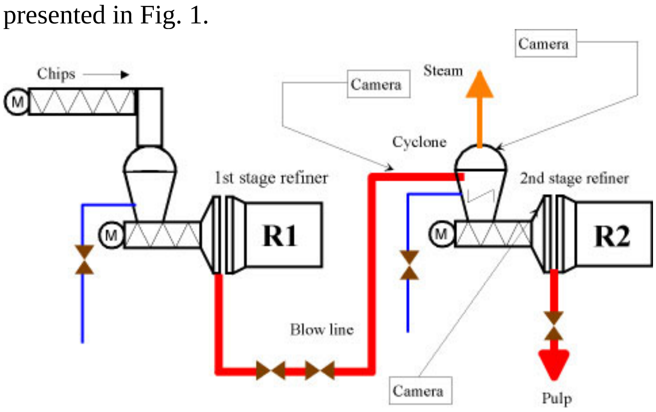

Fig. 1. Part of the process and the used installation positions of the camera.

Process signal and the synchronization pulse of the camera were logged simultaneously with the images at the frequency of 1 kHz, which gives the resolution of 0,5 ms between the image and the process sample.

3. PREPROCESSING OF DATA AND IMAGES

Due to the amount of the logged process data channels (46) and the sampling frequency (1 kHz), the total size of the logged data was large and at first it was sampled so that only data, which was logged during imaging, was enabled. Furthermore, the size of each taken image was 992*999 pixels, while the amplitude range (intensity or grey scale [1]) was either from 0 to 255 (8 bit) or from 0 to 1023 (10 bit). The total size of each image was either 1 Mbit or 2

Mbit. The amount and size of the images made the accurate examination of each individual image too much time and resource consuming, therefore only average intensities and intensity variations were calculated for each image.

The problem in the intensity calculation is that the lighting conditions were not similar all the time, for example step by step the windowed flange was covered with pulp. Effect of the lighting could be somewhat smoothed if occasionally a pure background image could be taken. In this case it was impossible to take a pure background image, because the process could not be stopped during the tests. Therefore a background image for each test set was created from the taken images of the previous test set.

One test set contains 300 – 500 images; a background image for that test set is created by searching intensity maximum for each pixel (intensity minimum, when the light source is behind the camera) and by gathering these maximums into one image. What can be seen clearly in these background images in Fig. 2, is that there is an increasing amount of pulp on the flange window, which changes the lighting condition. Any successful way to keep these windows completely clear was not found.

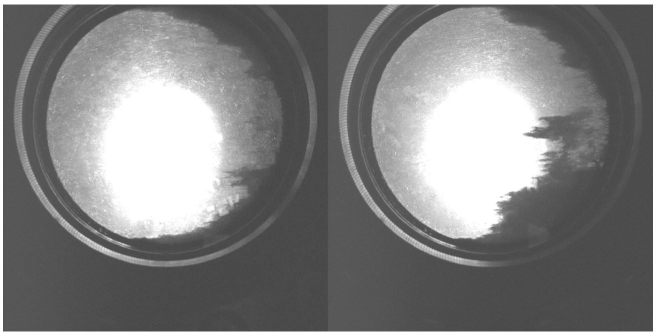

Fig. 2. Background images created from blow line test sets. Time interval between these 2 sets was over one hour.

Before the average intensities of the images were calculated, both from the background images and from the original images, parts like flange walls and extra reflections were masked out. One of the taken images is presented in Fig. 3 before and after masking.

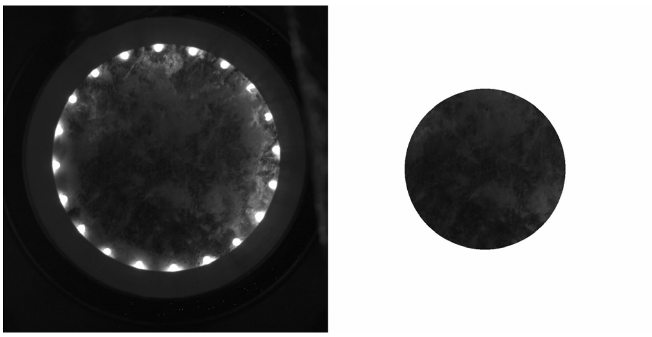

Fig. 3. On the left side an image taken from the casing of the 2nd stage refiner and on the right side the same image when the flange wall and the reflections of the light near the wall are masked out.

After the masking, average intensities of the images were calculated and due to differences between average intensities of the background images of different test sets, the proportional intensity correction was made to the every real image.

4. RESULTS OF THE IMAGING

The cyclone was the first position for the camera. It was positioned on top of the extra pipe connection and the light source was attached behind the camera (Fig. 4).

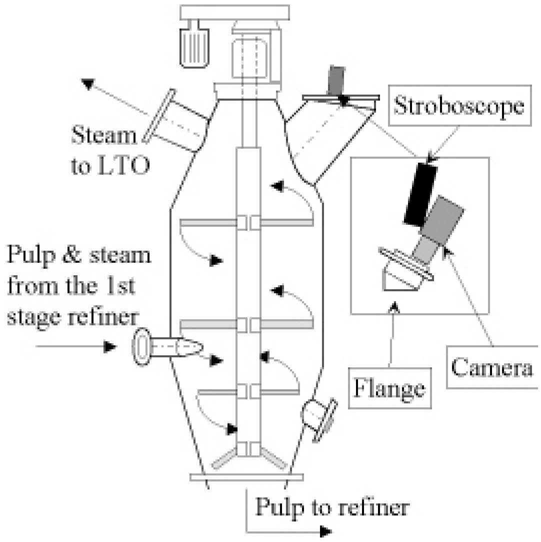

Fig. 4. The cyclone and the camera installation on top of it.

The objective of the cyclone imaging was to get a view of pulp flow on the bottom of the cyclone. However, lighting conditions were too problematic and the clear view to the bottom of the cyclone was not achieved. Instead of the bottom view, another feature was noticed from the images. The steam is not always transparent. In Fig. 5 is a set of images, where the saturated steam condensates and the view to the lower parts of the cyclone is completely lost.

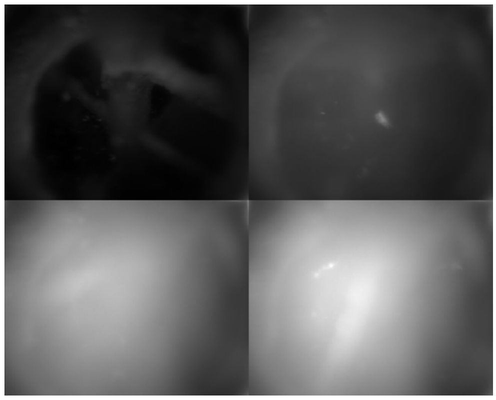

Fig. 5. Saturated steam condensates in the cyclone.

Logged data gives some answers to this phenomenon. When the load of the 1st stage refiner decreases, the steam production decreases. Furthermore, the pressure level in the line changes and eventually the saturated steam condensates. Likely this somehow changes the nature of the pulp, because at the same time there are changes in the level of the disc vibration of the 2nd refiner. In Fig. 6 are presented the intensity of the images and three different process variables; load of the 1st stage refiner, 2nd phase cyclone pressure and 2nd phase refiner disc vibration.

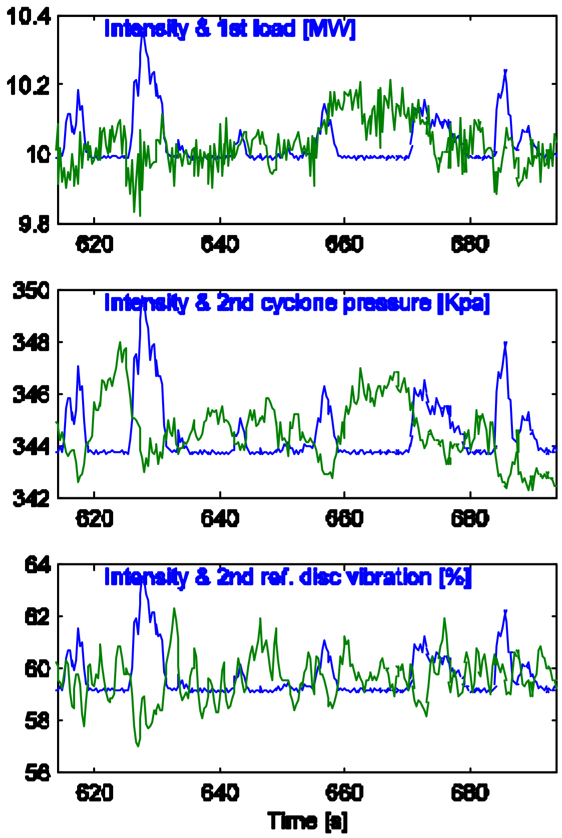

Fig. 6. Intensity and three different process variables. Peaks in the intensity can be seen in the process variables.

In cyclone images the intensity represents the stage of the condensation, saturated steam is transparent and the steam, which is below the saturation point, reflects the light. In Fig. 7 is shown the state of saturation for water in different temperatures and pressures [2].

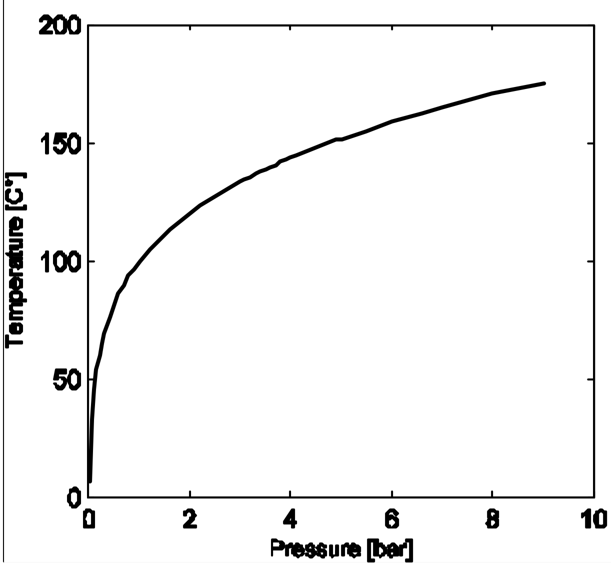

Fig. 7. State of saturation for the water; needed temperature in different pressures.

After the cyclone images were taken, the camera was moved either to the casing of the 2nd refiner or to the blow line. In these cases calculated intensity of the images characterized either the pulp flow in the blow line or the total amount of the pulp in the casing. Both, the pulp flow in the blow line and the pulp amount in the casing varied a lot, therefore intensity data was averaged. In averaging as shown in Fig. 8, the used window length was 2 seconds (25 images) and the sampling frequency was 0.625 Hz.

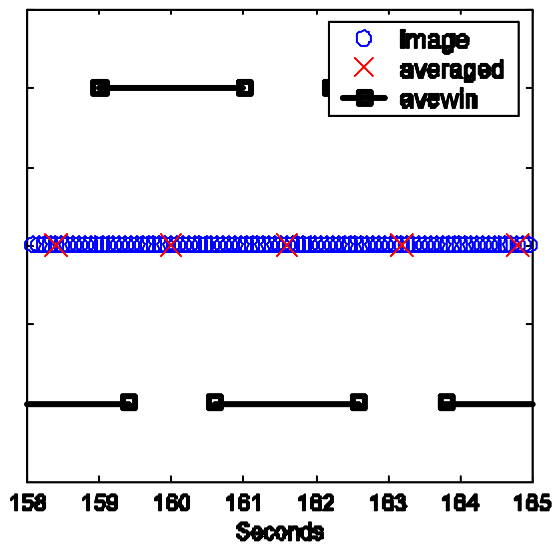

Fig. 8. Individual images, window length and the sample rate, which were used in averaging.

Various 2nd stage refiner loads and production levels based on the load of the feeding screw and pulp consistency can be seen directly from the images. The effect of different production rates and refiner load levels to the image intensity can be seen in Fig. 9.

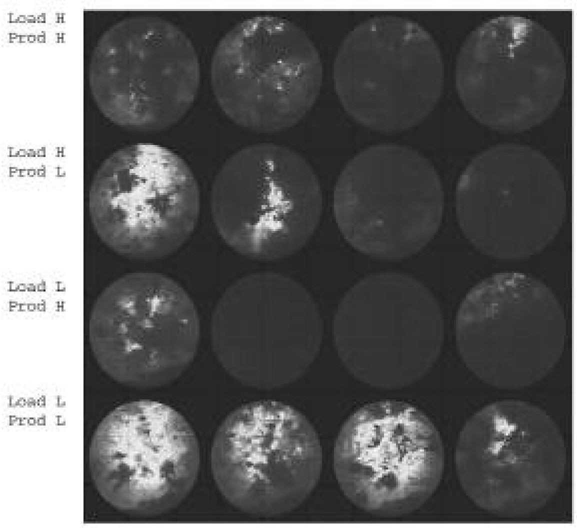

Fig. 9. The example images, which were taken from the blow line. In figure H = high and L = low.

Production rate of the refiner line is controlled by the feeding rate of the chips. When production rate is increased, more chips goes to the refiner and more pulp is generated. Increasing amount of pulp can be seen from the images, because the pulp in the blow line is thicker and the light does not penetrate it as well as before. The load of the refiner is controlled by changing the production rate or disc gap of the refiner. When the load is higher, more steam is generated and therefore the ratio between the steam and pulp in the blow line is greater, which is the reason why the light penetrates the pulp in the blow line better.

In addition to normal process situations, 5 different tests with changing different parameters were made. In these tests either the load of the 1st stage refiner, pulp consistency or pressure in the 2nd stage cyclone was changed. Used parameters are presented in table 1 and the effect of them to calculated and averaged intensities in Fig. 10.

Table 1. Test parameters.

Test n.	Load	Cons.	C. Press
1	9.5	Norm	Norm
2	10.5	Norm	Norm
3	8.5	Norm	Norm
4	9.5	Small	Norm
5	9.5	Norm	High

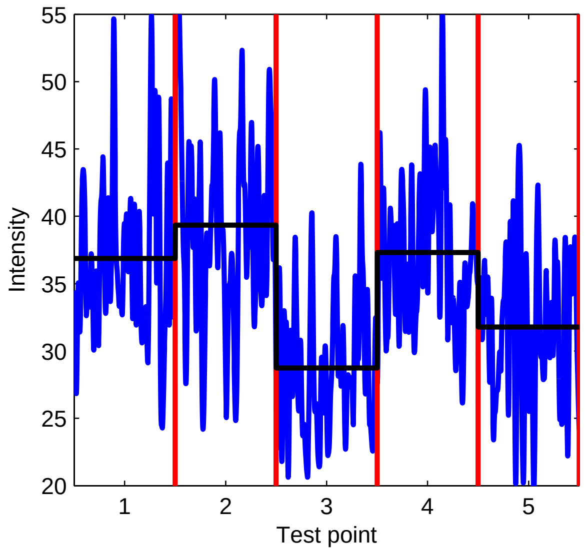

Fig. 10. Used test points and the corresponding intensities. Average intensity during each test point is marked with black line.

The effect of the load of the 1st stage refiner to the intensity of images can be seen clearly. Higher the load is the more steam is generated and so the pressure difference between the casing of the 1st stage refiner and 2nd stage cyclone is higher. Therefore the flow rate in the blow line is also higher. Same effect can be achieved by decreasing the pressure of the 2nd stage cyclone, reverse change is done in test point five. At the test point three, where the load is smallest, there is more pulp in each image than in images of any other test points. At the test point four, where the pulp consistency has been lowered, there seems not to be any significant difference in intensity when it is compared to the test point one.

Similar features were noticed in the images, which were taken from the 2nd stage refiner. The only exception was that the low intensity corresponds to “no pulp” in the image and vice versa. Reason for this was that the light source was behind the camera and the reflected light was measured.

5. CONCLUSION

Imaging gives another view of the process, which is hard to achieve in any other way. For example in this case, images showed that in some circumstances saturated steam in the refining process condensates, which might be a reason or consequence for some disturbances in the refining process.

It is reasonable and much faster to use some calculated features of the images and due to amount of the casing and blow line images, the reasonable way to search similarities between images and process data was to calculate average intensities of those images. Intensities had some correlation with process variables even if there were problems with the lighting. Yet the images left some unanswered questions and maybe the developing imaging systems and methods will give more answers.

6. ACKNOWLEDGEMENT

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