Short Term Scientific Mission in the frame of COST Action E48

Report

„Study of Paper Bale Sensor and paper stream control”

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Report COST E – 48

I spent two weeks in the frame of the **Short Term Scientific Mission** in Germany, in the **PTS** (The Paper Technology Specialists).
In PTS, I had a possibility to get acquainted with two new portable measuring systems:

- paper bale sensor
- paper stream control

Main objective of the mission was to study these systems, method of which is based on NIR spectroscopy.

On the first week I have studied and understood how can be applied the NIR spectroscopy for examining the contents of the paper. Then I observed the PBS and the PaperStreamControl PSC device in practice. I had the possibility to use these tools. On the second week I had the opportunity to visit a mill, where I could study how the PBS operated in mill environment.

Background

Recovered paper quality is one of the main topics in the field of paper recycling. In Hungary mainly old corrugated containers (OCC), old newspapers and magazines, and other types of recovered paper are used for the production of containerboard, printing-writing and sanitary-hygienic papers.
Recovered paper utilization rate is as high as 70%.

Some quality control methods and devices have been developed with some relatively good results for some recovered paper grades. Subjective, non – accurate and non – standardised controls generate mistrust between suppliers and clients. Measuring can significantly improve the trust between suppliers and buyers of recovered paper.
The quality monitoring of incoming bales has been extremely time – consuming and labour – intensive.

1. Three aspects of the Recovered Paper quality have to be controlled

- **Moisture content**: EN643 states that „Recovered paper and board will, in principle, be supplied with moisture of not more than the naturally occurring level. Where the moisture content is higher than 10% (of air dried weight), the additional weight in excess of 10% may be claimed back (whit the method of testing and sampling to be agreed between buyer and seller)"

- **Unusable materials content**: it consists of „non–Paper Components and Paper and Board determinal production".
  EN643 states that „recovered paper and board should, in principle, be supplied free of unusable materials, but where for specific grades a certain proportion of unusable materials is agreed between purchaser and supplier, it shall refer solely to the element described as Paper and Board Detrimental to Production"

- **Recovered Paper Characterisation:** EN643 describes what kind of paper should be in a bale, in order to consider it as a concrete quality (grade) of Recovered Paper. Quality Control examines the material supplied, in order to confirm if Recovered Paper delivered as a grade, is really this grade or not.

Visual evaluation is currently the standard practice, although it is expensive, imprecise and no longer reflects the state of the art. The requirements of "modern" recovered paper evaluation have even been specified by the CEPI Quality Control Task Force and can be boiled down to a common denominator. Such evaluation should:

- be simple to use;
- make reliable operation possible, and
- characterise the recovered paper comprehensively.

The NIR spectroscopy method is suitable for the above mentioned requirements.

2. NIR spectroscopy

NIR spectroscopy is the measurement of the wavelength and intensity of the absorption of near-infrared light by a sample. Near-infrared light spans the 800 nm - 2.5 µm (12,500 - 4000 cm-1) range and is energetic enough to excite overtones and combinations of molecular vibrations to higher energy levels. NIR spectroscopy is typically used for quantitative measurement of organic functional groups, especially C-H, O-H, N-H, and C=O. These are groups which we can find in almost every organic compound and of course in paper and most of the additives.

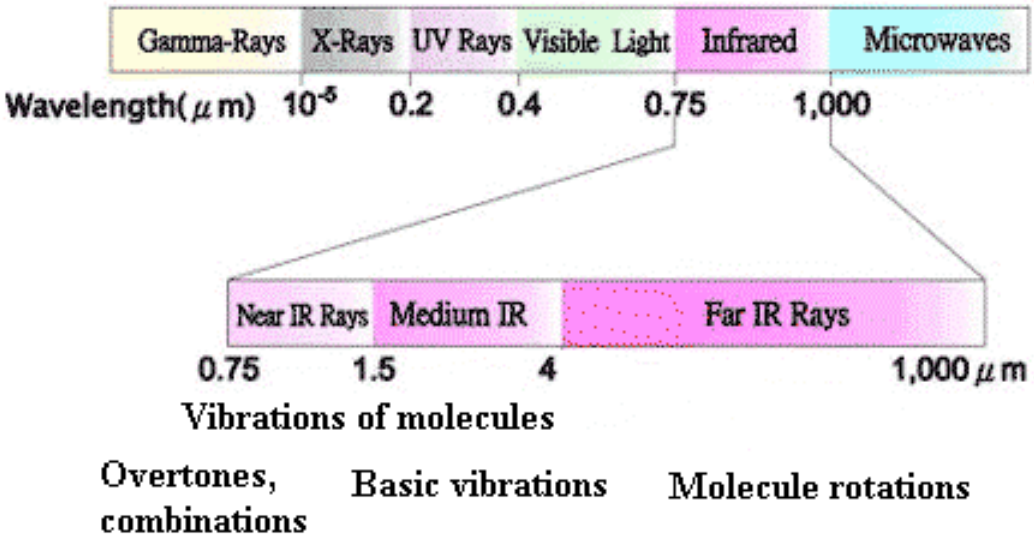


Figure 1.: Partition of spectral range of electromagnetic ray

The Near Infra – Red spectroscopy has been already used for several years in different sectors like food processing, chemical or drugs. As for papermaking sector, it is really an „emerging" technique for few years, and it is definitely a very „promising"

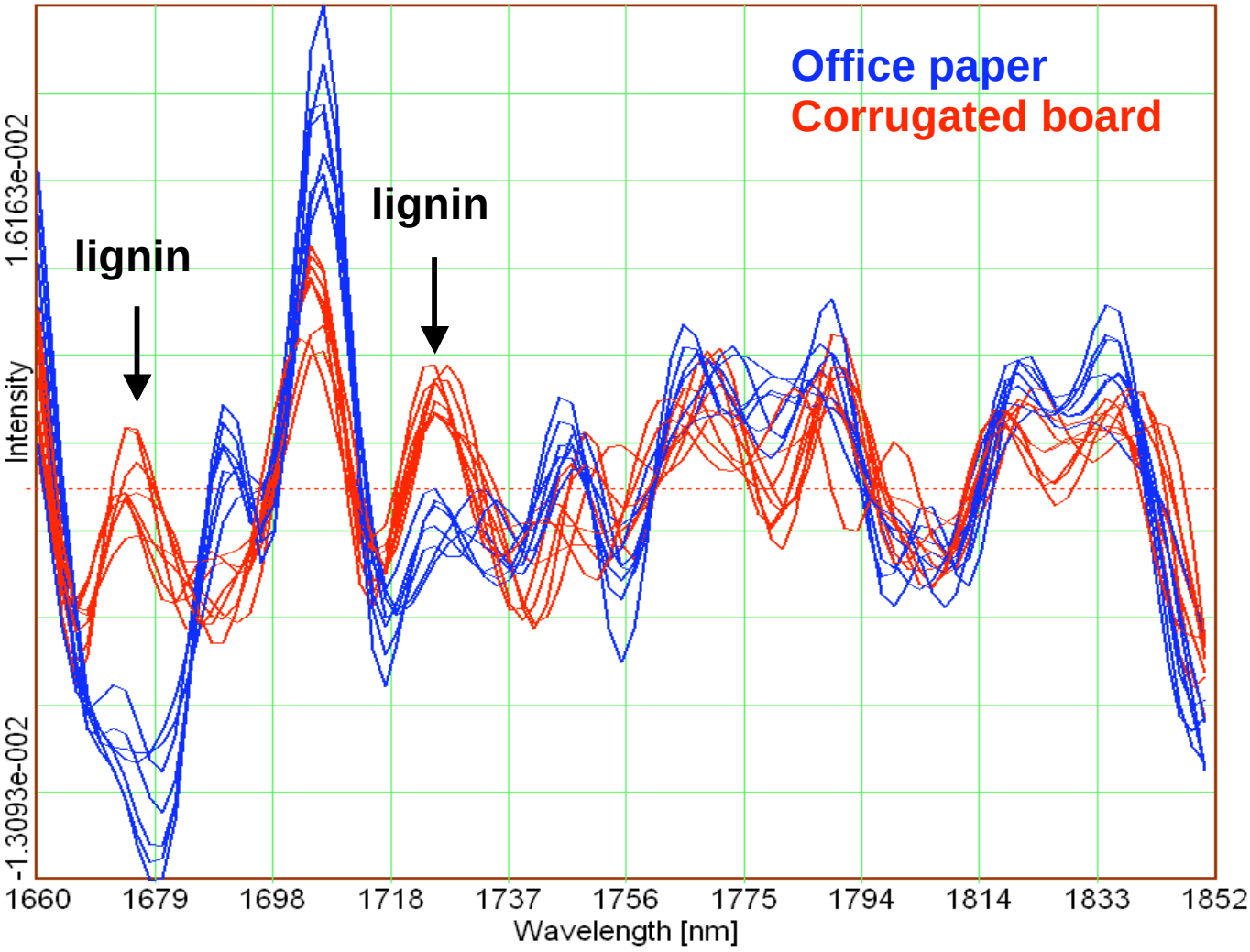


Figure 2.: Second derivate of NIR spectra of different paper types

technology for the future. These methods need to do a very important step of calibration in order to obtain the coefficients of the model. To do this learning, we need to know, for some particular samples, their spectra and the outlet data corresponding. Using together the inlet and outlet data, we can build the prediction model. Note that this calibration is certainly a very long step to develop the models, it spends a lot of time, but it is really crucial for the final result, and the good efficiency of the sensor.

Advantages of the NIR system are:

- High sensitivity with extremely short measurement times
- Fast moving products can be measured and evaluated
- Integration into an automatic process control is possible
- Identification of non-paper material, unwanted papers und others
- Easy combination of several identification algorithms possible
- Suitable for quality assessment and sorting of recovered paper

In the next chapters I present two tools which I met during my study trip in Germany, and are operating on the principle of NIR spectroscopy.

3. PBS – Paper Bale Sensor

The PTS started to develop a PBS tool many years ago, which could immediately measure the most important contents and quality of the incoming bales. The result of this development is the Paper Bale Sensor (PBS), portable measuring device, which operates on the NIR spectroscopy principle. So this tool can recognize and characterize the contents of the bales. The sensor is user-friendly and has a large display.

Figure 3.: The PBS device

3.1. The technical data of the PBS

Measuring device (portable):

Spectral range:	900 – 1680 nm
Mass:	5 kg
Dimensions (wxdxh):	175x250x260 mm

Measuring rod:

Length:	1,2 m
Diameter:	20mm

Drilling equipment:
Commercial drill
Or automatic drilling workstation

Advantages of the PBS device:

- A new approach to entry inspection of recovered paper
- Robust and user – friendly device
- Objective, fast, easy and reliable method
- Highly accurate and reproducible measurements
- Easy evaluation and storage of the results
- Portable, battery – powered device
- There is no need to prepare the recovered paper bales ahead of the measurement – the sensor works quickly and reliably with any kind of recovered paper from household collections to high – quality print trimmings.
- Low maintence requirements

3.2. Procedure of the measurement

A spiral drilling machine is needed for drilling a 25 millimetres whole anywhere in the bales. In contrast with the practice (the drilling had to be very deep to the centre of the bale) this whole, which is made for the PBS device can be of optional deep.
The spiral drilling is a regular machine which can be purchased anywhere, the nominal output is 1010 W and the maximum torque is 33 Nm.

- First step is a simple drilling into the bale. It can be done easily and in seconds.

- Second step: the actual analysis is performed by a measuring rod with sensor scanning the walls of the drill hole in the near infrared wavelength range. A pre-defined algorithm calculates the shares of individual bale constituents.

- Third step: the results are saved and promptly made visible on a large display. The results are stored automatically together with the grade designation and supplier data. At the push of button, the results may be transferred to a USB stick for further processing by conventional Windows programs.

The sensor should be calibrated before every measurement, which can be done by an etalon white colour.

Measurement conditions:

- The PBS may be used in a temperature range of – 10 ºC to 40 ºC, and works perfectly well even under the most adverse conditions (wind, shower).
- It may be operated in the battery mode for tree hours.

3.3. Measured parameters

The configuration currently embodies the following features:

- "Moisture", the most important parameter for incoming bales, is determined to an accuracy of 0,5% in a range up to 10%. Bales that clearly have greater moisture can be measured to an accuracy of 1%.

- Plastic parts contained in bales can be determined quantitatively with similar accuracy. Neither the type nor the nature of the plastic parts is important. The system can detect both polyethylene laminations

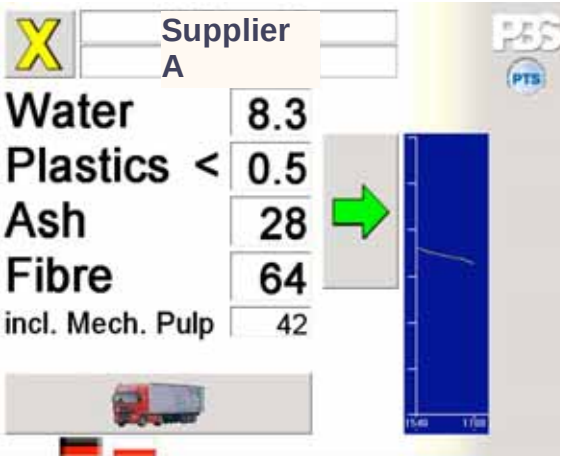


Figure 4.: Result on monitor of PBS

and more massive particles. The latter can be identified with the naked eye being undesirable contaminants.

- Last but not least, it is also possible to supply information about the ratio of fibres and filler in the bales. Like all other data, this information is expressed as per cent by weight of the bales.

The problem with most of the moisture measurement is that measurement is not carried out on the complete content of a delivered load. It is only carried out on a limited number of bales of each load and applied to the entire load.
One of the key questions was to be answered in the tests, that how long it takes to get statistically reliable results for a full truckload of recovered paper. The whole procedure takes around 20 minutes with the PBS device.

3.4. Trial measurements with PBS device

3.4.1. My experiences in the Tissue mill

During my visit the expert of the paper mill showed me the PBS in operation. We have measured a bale selected by chance from the incoming load. The bale was a mixed recovered paper shipment. The moisture was 18% in each hole which we have examined with the PBS device. The outside of bale seemed to be dry by visual examination, but during the drilling we could experience, that the pieces which came out from the holes were wet. Further steps could be made immediately towards the seller because of the quality of the load.
I could see another point of interest. The sensor was put on a material made in the mill and which I did not know. The monitor showed that this unknown material consists quite a large quantity of fibre and plastic. Afterwards I got to know, that this kind of paper is used for hygroscopic hygienic goods. The fibres are mixed with polymers which are able to absorb the moisture.

3.4.2. Solving a practical problem

On the second week of my STSM the software of PBS device had to be improved. I had the possibility to join in solving the problem.
We measured three bales sorting of 1.02, 1.04, 1.11, which stood in outdoors. Two holes were drilled in every bale, which we measured every five minutes. As the outside temperature was growing the ash content shown by the divice was first reducing, than growing.

We controlled the results with LECO AF700 automatic furnace. This furnace measured the ash and moisture content according to ISO 2144, ISO 1762, DIN EN 20287.

As an example, I have taken the result of first hole out of the others, beacuse this shows best the fluctuation, it can be seen well in figure 7.

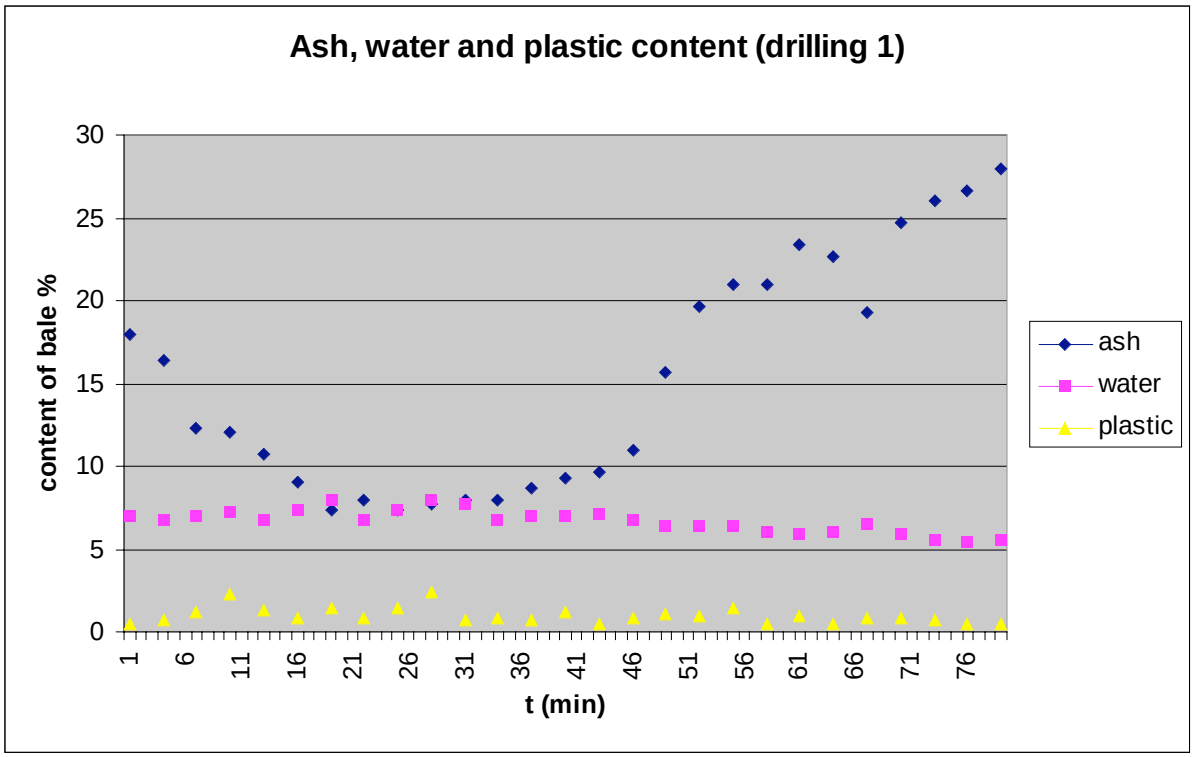


Figure 7.: Ash, moisture and plastic content of first drilling

Figure 8. shows the difference of data, which were measured with PBS and LECO.

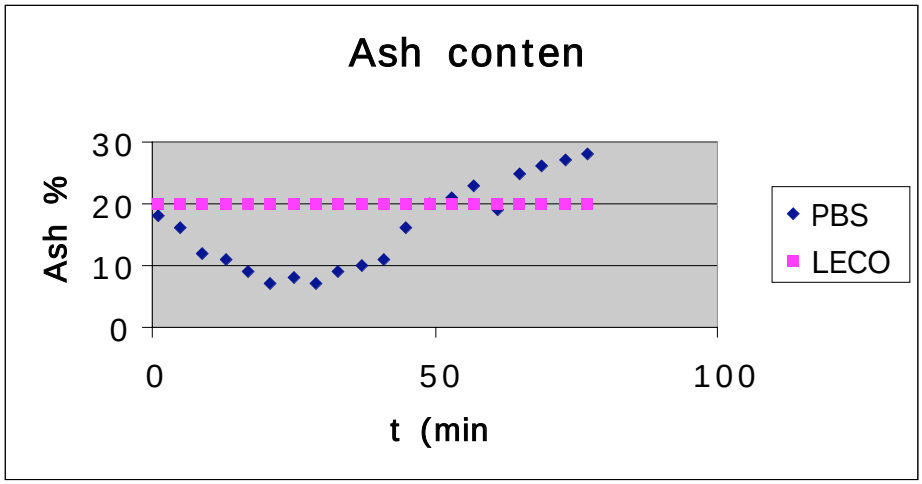


Figure 8.: Comparison of measuring of PBS and LECO

The reason of the false measuring was a mistake in the calibration software. For the sake of a mistake in the new version of the software the device could not measure the background spectrum, that is why it developed the dependence of the temperature. Before the measurement the PBS device was kept at room temperature, than it cooled automatically during the test but the hot sunshine warmed it up. The changes in temperature could cause the variation of ash content. (See: Figures 7 - 8.)
After a method optimization mistake of the software was corrected.

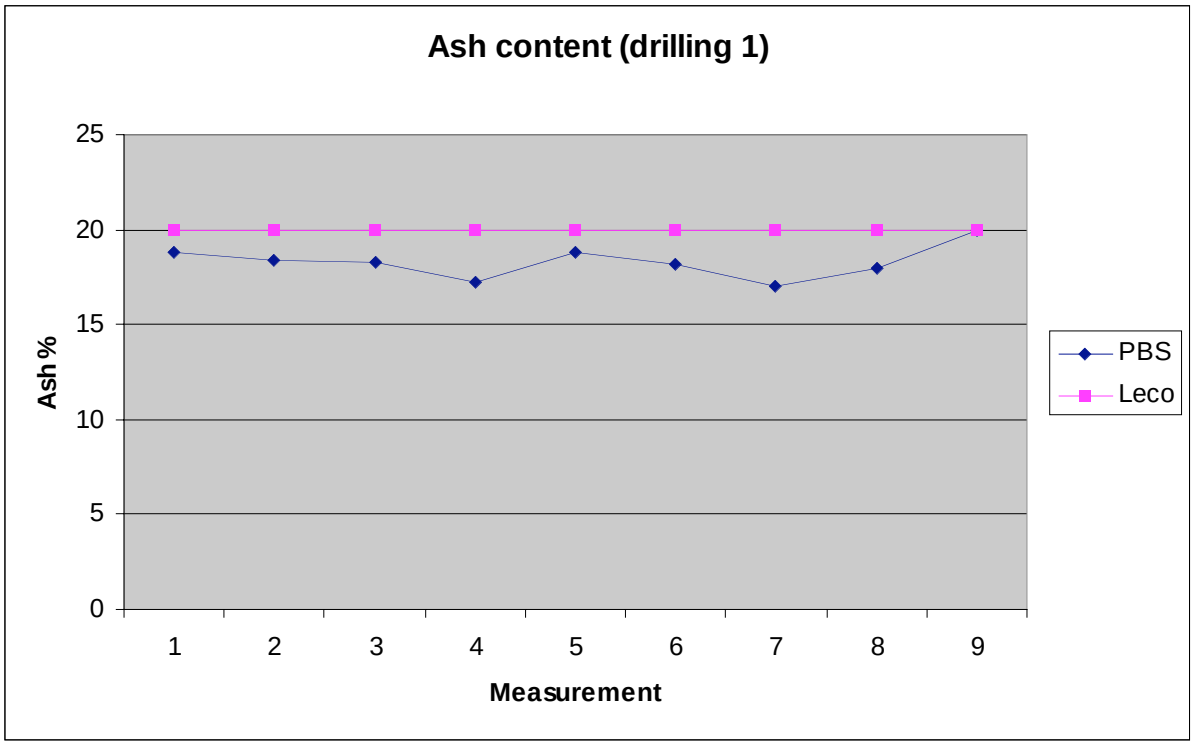


Figure 9.: Measure of ash content after the software optimization

The Figure shows the results of ash measurements after the software correction. The fluctuation of the results decraused, we got a real linear function.
In the future this problem will not cause any mistake.

4. PaperStreamControl

During my study trip the second tool I got to know another research project at PTS which is aimed at the quality control of loose recovered paper. The measuring system, “PaperStreamControl” is also based on the NIR spectroscopy. It satisfies the third point of the paper quality control, which is the selection of the different recovered paper.

The measuring system with the identification software which was developed by PTS is in a “learning” and testing period, it can successfully recognize the different paper and non-paper contents.
The sensor can be installed on any transport belt. The illustration below shows the spectrometer and test bench in a pilot-plan application.

Measuring range
1400 nm - 2200 nm

Resolution
2 nm

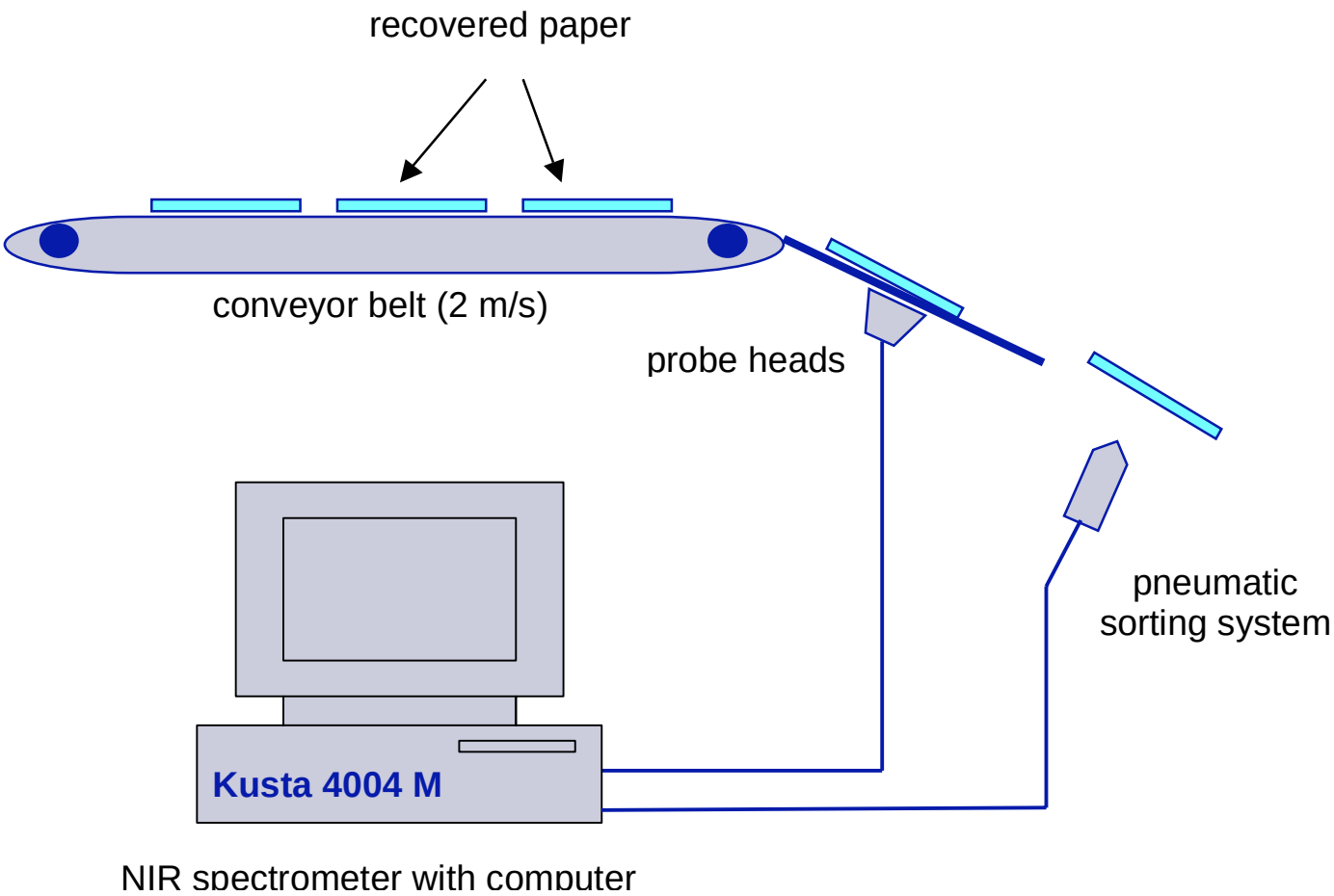


Figure 5.: Process spectrometer with an evaulation unit attached to a transport belt

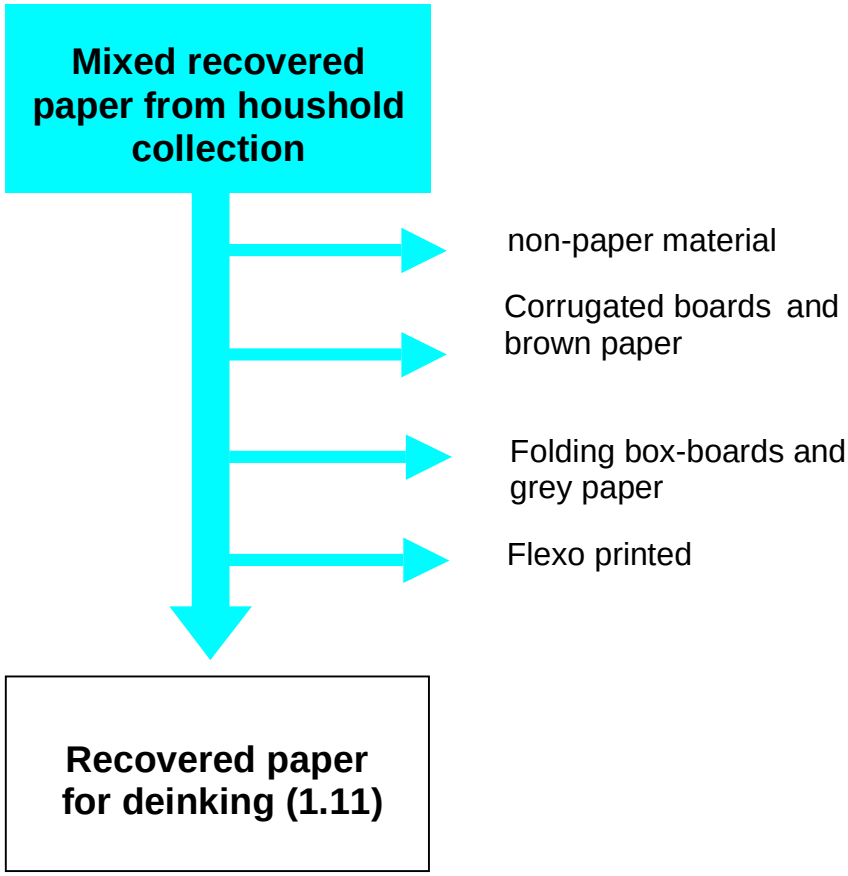
Measuring probes
Multiplexed with up to 64 probe heads

Scan rate
max. 70 Hz

The measuring procedure was ultimately tested on a mix of recovered paper from household collection. The next picture shows the identification of the individual fractions in the recovered paper mix.

The following three applications are conceivable for the use of this measuring procedure:

- Selective and improved sorting of mixed recovered paper – in combination with a transport belt and a pneumatic system.
- Inspection of incoming recovered paper shipments – the delivered paper is inspected immediately and then either accepted or rejected.
- Monitoring the recovered paper flows – control the deinking process.



Picture 6.: Identification algorithm for sorting of recovered paper

Further aim of the developing is to make PaperStreamControl able to recognize the difference between the flexo and offset printed newspaper.

The two printing methods cannot be differed by visual examination. The procedure of deinking is different in these two types of printing method. In recovered paper treatment, however, these inks are causing serious problems because they cannot or at least not completely be removed by deinking processes. It is therefore desirable for

graphic paper producers to detect flexoprints in the incoming recovered paper, measure their shares and, if necessary, sort them out.

By means of this technique, papermakers will be able to largely automate the incoming quality control of sorted graphics for deinking, thus making it much more comprehensive, efficient, cost- and time – saving.

In Hungary the flexo printed newspapers are not recycled yet.

5. Further research and cooperation

The visit in the Tissue mill has made me understand that the PBS device could be very useful for the paper recycling companies. According to experiences of the above mentioned topic, I have set the following aims:

With the contribution of the PTS, I would conduct presentation of the PBS device the paper milles of tissue, egg tray, corrugated cardboard in Hungary.

I plan to write an article about the PBS device in some paper industry related magazines.

As a joint activity with the PTS we could have the PBS device registered in Hungary. If it is possible we could do the reference measurements of the device in addition to the Polish, German, Spanish and Austrian measurements. We would control the results in regular way:

- Contents of ash – ISO 1762:2001
- Fibre contents – with Bauer-Mcnett method
- Moister content – oven–drying method
- Plastic content with selection, and then gravimetric method

We would control the newspaper, mixed paper waste, and supermarket waste.

6. Conclusion

My study trip in the frame of the Short Term Scientific Mission was very interesting and successful. I have got a lot of new information about the subject I have chosen. The two measuring tools have arouse my interest in the importance of recycling. I have faced some problems in the paper industry which we do not lay enough stress on in Hungary yet.

In the future I would be more than happy to cooperate in any way with PTS. I could learn from the results of the new developments either in electronically or personally.

As I mentioned in the previous chapter – Further research and cooperation – I would like to ease the debate between the paper recycling mills and their customers.

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