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EFFECT OF VARIATIONS IN A PULP FLOW ON SAMPLING AND PROCESS MEASUREMENTS

Tuomo Timonen, *Jouko Halttunen*

Institute of Measurement and Information Technology, Tampere University of Technology, Tampere, Finland

Abstract – A pulp suspension flowing in a pipe has a tendency to form a profile: The properties of the pulp vary significantly in a cross-section of the flow. This causes problems both in online-measurements and sampling. The importance of representative sampling is further emphasized by the fact that samples taken are often used as reference in calibration of measurement instruments.
The problem of representative sampling and the variation of quality in a pulp flow were studied using equipment with which it was possible to take samples from different depths in the flow and thus determine the variations.
Experimental testing was conducted in different process conditions and with different pulp types. The results of the tests showed that the quality variations in a pulp flow were more profound than initially thought: Several pulp properties have significant profiles within the flow that depend on the type of the pulp and the flow conditions. The variation of pulp properties is large enough to somewhat affect all measurements made from the flow in question.
The findings of the study suggest new guidelines for sampling and installing instrumentation when a pulp suspension flow is measured.

Keywords: Pulp, Flow, Sampling

1. INTRODUCTION

In pulp and paper industry the quality of pulp is most often determined either by processing samples taken from a pulp flow or through online instruments measuring the pulp as it flows in a pipeline. Sampling is also used as a method to get reference results with which the online instruments can be calibrated.

Due to the non-Newtonian flow properties of pulp suspension, pulp flowing in a pipeline has a tendency for variations in quality, which means that the quality of the pulp is significantly different near the pipe walls and near the centreline of the pipe.

The properties of pulp suspension flow have not been thoroughly studied, though some theoretical and experimental results on pulp suspension flow properties and sampling of pulp flows have been presented in [1], [2], [3] and [4]. However, these results are inconclusive with respect to variation of pulp properties within the flow.

In order to get a clear picture of variation of pulp properties in a pipeline, special sampling equipment was designed for the purposes of the study. The experimental part of the study clearly shows that the variation of pulp properties within a pipeline is more profound than initially thought. It has become evident that before sampling a pulp flow or installing instruments, which measure the flow in some way, careful planning and study of the current process conditions is required. Furthermore, the study shows clearly that there is a need for further development of sampling and measurement procedures.

2. PULP SUSPENSION FLOW

Flow properties of pulp suspension differ significantly from those of Newtonian fluids such as water. Pulp suspension is a two-phase or even a three-phase system including water, wood fibres and in some cases air bubbles. Due to the complexity of a multi-phase flow, theoretical models that would accurately describe the properties of pulp suspension flows have not been successfully developed. However, the basic properties of pulp suspension flows are known.

Pulp suspension flow behavior is heavily dependent on two factors, the consistency of the pulp and the flow velocity. At low consistencies the pulp suspension behaves much like water but as the consistency increases the behavior changes drastically at a consistency at which there is a possibility for a web to be formed. This border consistency depends on the type of pulp. In addition to the main factors mentioned, also the properties of the flow channel (in this study a pipe) affect the behavior of the flow. [3]

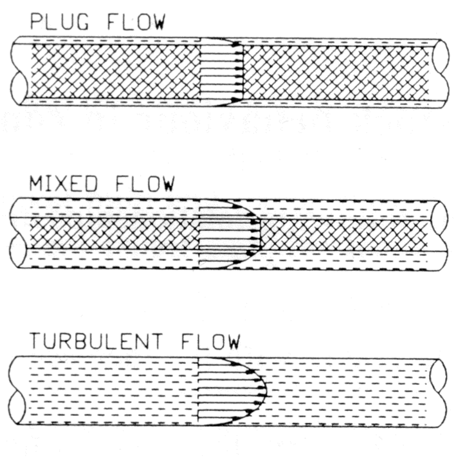

Figure 1 Flow regimes of a pulp suspension flow. As the velocity of the flow increases the flow becomes more turbulent. [5]

The flow regimes of a pulp suspension flow are illustrated in Fig. 1. At small velocities the pulp suspension forms a plug flow, in which the fibres do not touch the pipe wall and there is a narrow boundary layer of water between the flow and the wall. As the velocity increases, the thickness of the boundary layer increases and turbulence starts appearing while the center of the flow remains plug-like. This flow regime is called mixed flow. As the velocity further increases, the plug disappears and the whole flow cross-section becomes turbulent. [4, 2]

3. SAMPLING AND USED EQUIPMENT

The basic concept of sampling involves dividing a large body of material, in the case of this study a pulp flow in a pipeline, into a number of smaller portions. If the material was homogenous, no problems would arise. In this case the sampled material is heterogeneous and the different fibre-fractions of the pulp are not evenly distributed throughout the entire flow.

A representative sample means that the values of the variables of interest are the same in the sample and in the main flow and they can be adequately measured from the sample. Another aspect to consider is the uncertainty of a sample, the determination of which is in most cases impossible due to the lack of proper reference. It can be stated that the uncertainty of a sample is a sum of uncertainties of all the stages of sampling.

$$u(y) = u_m(x_m) + u_i(x_i) + u_h(x_h) \qquad (1)$$

Equation (1) determines the standard uncertainty $u(y)$ of the sampling and calibration process. In (1) $u_\mathrm{m}(x_\mathrm{m})$ is the methodological component of uncertainty, $u_\mathrm{i}(x_\mathrm{i})$ is the instrumental component and $u_\mathrm{h}(x_\mathrm{h})$ is the human component. Values of these components of uncertainty can be somewhat approximated, but the values are heavily dependent on the methods (standards) used and the proficiency of the laboratory staff. Instrumental uncertainty can be assumed insignificant compared to other factors when modern laboratory equipment is used. [1, 3]

An important aspect considering the representativeness and uncertainty of the sample is the method with which the sample is drawn from the main flow, since this part of the sampling procedure often causes most variation to the quality of the sample. In this study the method of taking the sample was developed based on earlier studies and previous sampling experience and the method was kept the same throughout the study. The samples were taken in the following way:

1. The sampler valve was opened to achieve a steady isokinetic flow. The required sampler pipe flow velocity was calculated using the main pipe and the sampler pipe dimensions and the flow velocity in the main pipe.
2. The pulp suspension was let to run for a few seconds to ensure a steady flow and to remove air bubbles, traces of the previous sample etc. from the sampler pipe.
3. The sample container was rapidly brought under the flow and filled carefully avoiding splashing and overflow, which could have affected the sample consistency.
4. The sample container was removed from the flow.
5. The sampler valve was closed.

The sampling equipment used was designed specifically for the purposes of the study. The sampling arrangement and the variable sampling parameters are shown in Fig. 2.

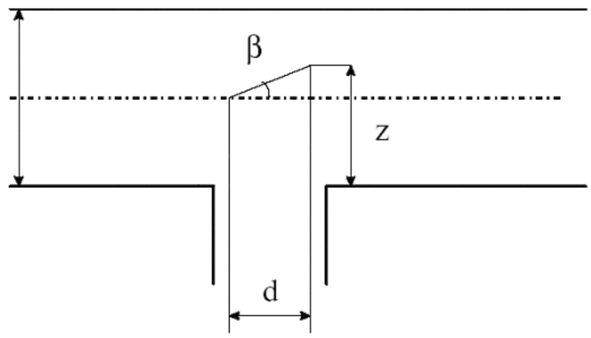

Fig. 2. The varied parameters of the sampler used in the study.

The varied parameters were the dimension of the sampler pipe *d*, the insertion depth *z* and the angle of the sampler end *β*. Of these parameters the insertion depth was found to be the most significant one when studying the variation of pulp properties.

4. EXPERIMENTAL RESULTS

It became clear at the early stages of the study that the focus would be on consistency profile of a pulp flow since the range of consistency variations was the most profound result of the study.

Consistency profile of a pulp flow was found to be dependent on the flow velocity, type of pulp, average consistency of the pulp and the location in the process. The average consistency of the pulp is an obvious factor in the consistency profile forming: As the consistency arises the fibres in the pulp suspension begin to form flocks and a consistency profile is formed.

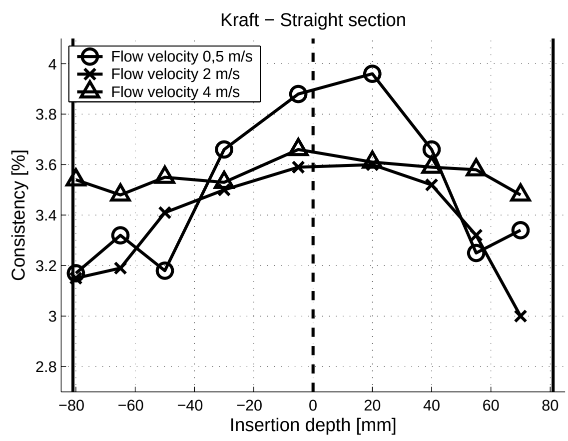

Fig. 3. The effect of flow velocity on the consistency variation within a cross-section of the flow.

Fig. 3. shows the effect of the flow velocity on the consistency variation in the cross-section of the flow. The flow velocity affects the consistency profile strongly. As the flow velocity increases, the pulp flow becomes turbulent and the dry material is more evenly mixed throughout the flow. Therefore, at higher flow velocities the consistency profile is flat and the lower the flow velocity the stronger consistency profile appears.

The type of pulp strongly affects the consistency profile of the flow due to the different water absorption properties of the fibers in different pulp types. Also the dependence on the flow velocity is dependent on the pulp type. Fig. 4. illustrates the effect of the pulp type on consistency variations. It can be seen from the figure that kraft forms a much stronger profile than either machine stock or thermomechanical (TMP) pulp.

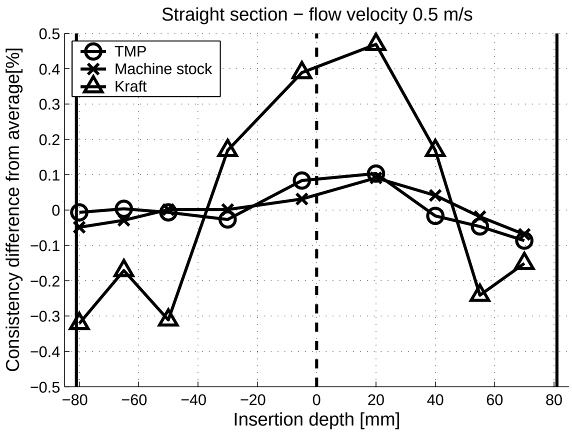

Fig 4 The effect of pulp type on the consistency variation within a cross-section of the flow.

Location in the process also has a significant effect on the consistency variations within a cross-section of the flow. Downstream of a bend the flow is disturbed by the bend and thus the consistency profile is also different from that of a flow in a straight section of the pipe. An example of the distorted profile measured one D downstream of a 90° -bend is shown in Fig. 5.

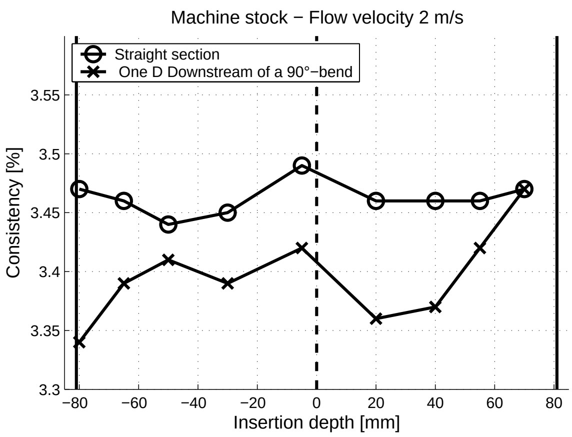

Fig. 5 The effect of location in the process on the consistency variation within a cross-section of the flow.

Other pulp properties were also studied, but profiles of such significance as consistency profiles were not found, although some variations in ash-concentration and fibre-length do occur within the flow. Based on the results, the correct way to take a sample is heavily dependent on the purpose of sampling. In most cases it is enough that the sample is taken in the same way every time so that the samples can be compared to each other. Whatever the purpose of sampling is, as much knowledge of the process in question as possible should be gathered and preferably the velocity and consistency profiles of the pulp suspension flow should be determined. When the conditions in the process to be sampled are known, the location of the sampler can be chosen to fit the purpose of the sampling and a correct type of sampler and a correct sampling method can be chosen for the task.

5. EFFECT ON PROCESS MEASUREMENTS

As stated in the previous chapter, a sampling task has to be carefully designed in order to achieve correct results. The problem with online measurement instrumentation is even more profound. Most of the measurements are made at a certain point of the flow only and since the properties vary within the flow, the result can be faulty due to wrong installation. Furthermore, many flow and consistency measurements are heavily dependent not only on one of these variables but both.

Often in paper mills the accuracy of consistency measurements is monitored by laboratory measurements made from samples taken from the flow. The results of this study suggest that this approach should be considered with extreme caution. In a situation shown in Fig. 3 the consistency difference between the centreline of the pipe and the walls of the pipe is almost 1 consistency-% that is 25 % of the average level measured. If a sample was taken near the wall of the pipe and used to calibrate a consistency measurement, the measurement results would significantly differ from the correct consistency.

Calibration procedures should take the variation of pulp properties within a suspension flow into account as sampling remains the easiest way to gather knowledge of pulp quality for calibration purposes and the representativeness of sampling is usually questionable.

6. CONCLUSIONS

The large variation of pulp properties in a flow suggests that several guidelines for sampling and installing measurement instrumentation should be somewhat revised.

How a sample should be taken from a pulp suspension flow is the central question of this study. The correct way to take a sample is heavily dependent on the purpose of sampling. If a sample is taken just to monitor the quality of the pulp during normal production in the mill, the representativeness is not as big a problem. More often than not it is enough that the sample is taken in the same way every time so that the samples can be compared to each other. If a sample is to be used for calibration or adjustment purposes, the representativeness becomes more important.

Usually it is said that a sampler should be installed in a pipe section where the pulp suspension flow has as few disturbances as possible. Results of this study suggest that this old guideline for sampling is somewhat faulty. Based on the results, a sample should be taken from a suspension flow on a turbulent region so the main pipe flow velocity should be high enough as this causes the pulp to be more evenly mixed within the flow.

Process measurements in a pulp flow are problematic due to the heterogeneity of the measured medium and the variations occurring due to the process variables. Based on the findings of this study it can be recommended that measurements in a pulp flow should be designed in such a way that they would be independent of the variations of the flow, and thus the result would not be based on a single point of a larger volume.

Sampling procedures and parameters of the sampler have not yet been very thoroughly studied and further study is needed as long as manual sampling remains in use. And while the automated sampling systems are being developed, the perfection of these designs constantly requires more precise knowledge of the phenomena of the pulp suspension flow. Findings of this study provide information on pulp suspension flows for calibration purposes and offer guidelines for designing new sampling procedures.

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Authors:
Tuomo Timonen
Phone: +358-3-31152642,
Fax: +358-3-31152171, tuomo.timonen@tut.fi,
Jouko Halttunen
Phone: +358-3-31152485,
Fax: +358-3-31152171, jouko.halttunen@tut.fi,
Institute of Measurement and Information Technology, Tampere University of Technology, Tampere, Finland.
P.O.BOX 692, 33101 Tampere, Finland