Preferred citation: H.W. Sack. The measurement of electrokinetic effects on a paper machine. In **Fibre-Water Interactions in Paper-Making**, *Trans. of the VIth Fund. Res. Symp. Oxford, 1977*, (Fundamental Research Committee, ed.), pp 173–177, FRC, Manchester, 2018. DOI: 10.15376/frc.1977.1.173.

THE MEASUREMENT OF ELECTROKINETIC EFFECTS ON A PAPER MACHINE

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DURING every minute of operation of a typical paper machine several square kilometers of interface between the solid and liquid phases of the pulp suspension pass down the wire. These interfaces possess a number of special properties. The formation of an electrical double layer on the surface of the solid phase, for instance, influences to a large extent the process of sheet forming, the retention of fibres, fillers and sizing agents and, in turn, the characteristics of the finished sheet. There is understandably, therefore, a strong interest in obtaining measurements of these interfacial characteristics with the intention of optimising the operation of the process and the performance of the products. This interest is demonstrated by the number of publications which have appeared on the subject over the last few years. Melzer,[1] for example, cited as many as 102 papers in 1972 and since then many more have appeared.

Within the electrical double layer a potential difference exists between a plane near the surface of the solid phase, where charges are rigidly bound, and a plane in the liquid phase where charges are still barely mobile. This potential is called the zeta potential (ZP). The ZP causes the known effects of electrophoresis, electro-osmosis, streaming potential and related phenomena. All of these effects can be used to measure ZP.

At present the literature contains only one reference to an instrument capable of automatic and continuous measurement and recording of the streaming potential.[2]

The desirability of being able to record the measured values of ZP is illustrated in Fig. 1. The values of ZP shown in the figure were obtained from the white-water of a paper machine using a micro-electrophoresis technique on an instrument developed by Riddick. Values of pH, conductivity and white-water solids content were measured simultaneously. These time consuming measurements, however, did not provide sufficient explanation

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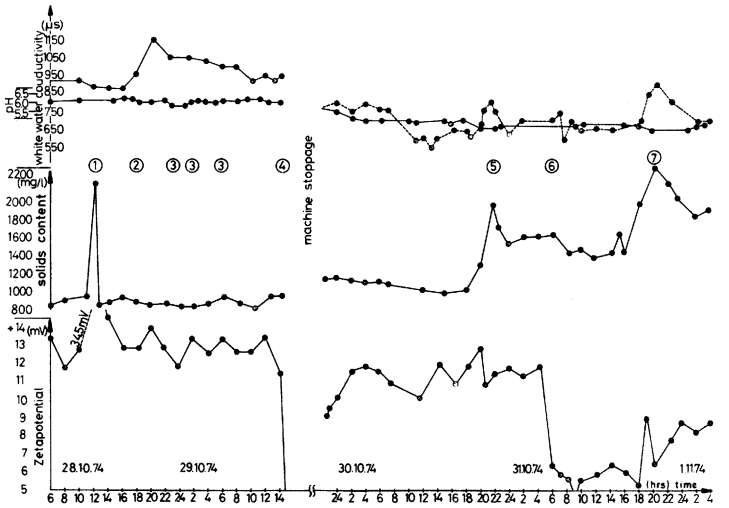

Fig. 1—Measurement of the zeta potential, solids content, conductivity and pH of the white-water on a paper machine. (Explanation in text.)

of the actual events. For example at point 1, in Fig. 1, the ZP jumps, without obvious reason, to a high positive value; at the same time the white-water solids content trebles. Equally, at point 2, again for no apparent reason, the white-water conductivity rises. At point 3 the ZP fluctuates because different amounts of broke were added. The point at which the addition level of cationic wet strength agent was reduced is shown by point 4. The white-water solids content, therefore, rises only slightly—by about 20 per cent. At point 5 the solids content doubles, although two hours earlier, for a change of grade, the filler concentration was reduced from 5 to 4 per cent and the ZP remained constant. The conductivity then rose for a short time. At point 6, the ZP drops significantly for no obvious reason. Perhaps, from that point onwards, the interval between sampling and measuring was reduced! Point 7 shows how the ZP, solids content and conductivity rise steeply after doubling the dry strength resin concentration.

Consideration of the data presented in Fig. 1 leads one to draw only two definite conclusions.

1. As well as being time-consuming to measure, the influence of the ZP upon the process and the quality of the product is open to many interpretations and is so unclear or even irrelevant that the results do not justify the effort.

2. Sampling at discrete, regular time intervals does not provide results which can be interpreted with any degree of confidence. Thus, an automatic, continuous method of measurement has to be developed.

The thoughts expressed in conclusion 2 prompted us to develop the measuring instrument mentioned earlier, measuring the streaming potential. Other methods are feasible and three of them are offered for discussion below.

1—*Measurement of streaming potential on the paper machine wire*

BASICALLY, the function of the paper machine wire is to separate the solid phase from the liquid phase of the pulp suspension. In this separation process the same kind of shear forces act upon the electrical double layer as in a usual streaming potential measuring cell. Between the upper and lower side of the wire a potential will develop which will be proportional to the ZP. Due to the relatively low thickness and density of the sheet, however, this potential will be substantially weaker than in the usual measuring cells. But since the whole width of the wire is available for the siting of a suitable arrangement of electrodes this disadvantage can be partially overcome by increasing the covered area.[3] Fig. 2 shows such an arrangement. An electrode (3) is partially immersed in the pulp suspension from above. The other electrode, (4), is positioned at the front of a foil over which the white-water is flowing. This arrangement has the additional advantage that it can be installed on any paper machine at extremely low cost.[4] Some difficulties are involved in isolating the relatively weak signal from interference which may reach the measuring circuit by way of the machine framework.

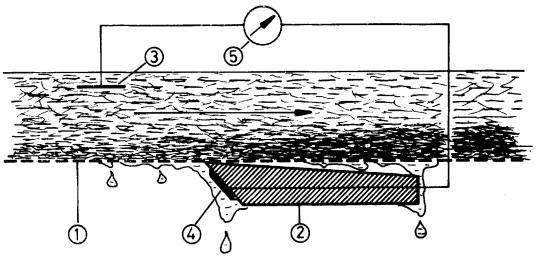

Fig. 2—Arrangement of electrodes to permit the continuous measurement of the streaming potential on the wire of a paper machine

1 = wire, 2 = foil, 3 = upper electrode, 4 = lower electrode, 5 = measuring equipment

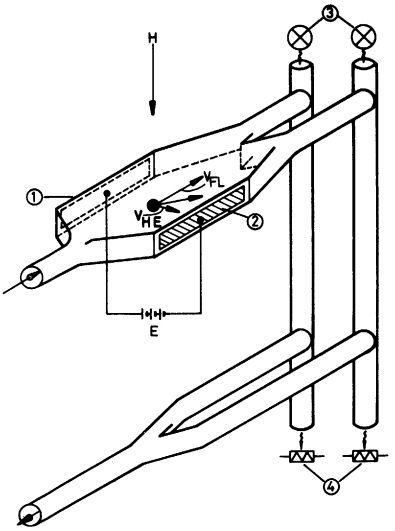

Fig. 3—Combined schematic drawing showing the method of operation of a continuous electrophoretic and a continuous magnetophoretic ZP Measuring cell. 1 + 2 = electrodes, 3 = bulbs, 4 = light sensitive elements

2—*Electrophoretic zeta potential measuring cell*

FIG. 3 shows an electrophoretic continuous measuring cell. In this cell the electrodes are labelled (1) and (2). In the absence of a field the particles which make up the solid phase of the pulp suspension pass through the cell with velocity V_{FL} in the direction indicated by the arrow. When the field is applied the particles experience a force perpendicular to their direction of flow which deflects them with a velocity of V_E. The resultant direction of movement is shown by the unlabelled arrow. At the exit of the measuring cell the stream is divided into two equal parts. Each part is piped to identical turbidity measuring curvettes. The extent and direction of the measured turbidity differences are related to the value and sign of the ZP of the suspended material.[5]

3—*Magnetophoretic zeta potential measuring cell*

IF THE electric field, produced by the potential E in the measuring cell shown in Fig. 3, is replaced by a magnetic field H perpendicular to the plane of the cell then the suspended particles, similar to the Hall effect, can likewise

be deflected from the original flow direction, V_{FL}, with a velocity V_H. The direction and magnitude of the deflection is again proportional—apart from a cell and material constant—to the value and sign of the charges which are firmly bound to the suspended particles, namely the zeta potential. The continuous measurement of turbidity then yields a continuous quantitative determination of ZP[5].

All of these methods were used in trials. For the streaming potential method, experience has been gathered over several months. After optimising the electrodes and by using the arrangement shown in Fig. 2 this method has proved to be the least susceptible of the three to disturbances. However, there is still room for improvement in regard to the correlation between the values obtained using this technique and those obtained from the Zeta-meter. Stray fields surrounding the paper machine have not yet been completely eliminated from the measuring signal.

The continuous electrophoretic method has been tested in the laboratory. It supplied reliable data provided a laminar flow was maintained in the cell and provided an accurate measurement of turbidity was made. It has also been shown to be suitable for use with coating mixes.

The continuous magnetophoretic method provided some promising results but these remain to be confirmed.

Of the three methods we prefer the first—the streaming potential method. By employing this technique we are sure that, given time we can make a worthwhile improvement in our products.

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Discussion

Mr E. Shriver I would just like to ask Dr Sack what he hopes to gain and how he hopes to improve his papermaking with this information.

Sack Firstly, we have learned from our measurements that you can observe peculiar phenomena which can sometimes be traced down to operator variables. Secondly, we try with some success to find correlation between the normal zeta potential as measured with the Riddick apparatus and our measurements on the paper machine. We are sure that there are correlations but there are also correlations between our measurements and pH, conductivity, hardness of the water or temperature of the water. What we now have to do is to separate all of these influences, and in this way we hope to learn how to produce better quality paper.

Mr J. B. Sisson Could you give a clearer description of the upper electrode and would you care to comment on what the effect of its design might be in relation to the paper machine speed?

Sack Your question leads me to believe that you have a similar apparatus on your machine! We have tried a wide range of metals. Since our mill makes photographic base paper we must look for clean materials, for example, not copper. We use stainless steel, using the same material for both upper and lower electrodes. You can find differences if you use bronze or plastic wires. of course. The effect of the machine speed is that it influences the shear forces and therefore the streaming potential.

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