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OVERVIEW OF PHYSICAL FORMING

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Abstract only—complete paper in Volume III

Abstract

In this overview, *forming* is defined more generally to include all processes from thick stock dilution with recirculated white water (*mix* production), to the final dewatering of the wet web on the wire.

Grammage variations in the finished paper are generated mainly during the forming process. These variations can be expressed as *mass formation* in the small scale range and MD-, CD- and residual variance for large scale variations.

Mass formation can be evaluated off-line using beta radiography, combined with micro densitometry or image analysis. A new technique involving direct recording of *electron beam transmission* is under development, with promises of faster processing, perhaps even on-line, and higher geometrical resolution. Characterization techniques based on the *co-occurence matrix*, especially suitable in image analysis, can be a useful complement to the traditional power spectra.

It has recently been conclusively demonstrated that in flowing fibre suspensions, flocs are kept together by the bending forces of the fibres involved. To study the dynamic behaviour of flowing fibre suspensions, modern video techniques and image analysis are being applied.

The build-up of the fibre mat is considered to be a *filtration process* under normal conditions. This

process posesses an inherent "self healing" effect on local grammage variations. The mass formation of a laboratory sheet is for this reason superior to that of a *random sheet*. The higher mix consistencies used for machine made sheets cause floc generation, and usually results in a worse large scale mass formation than that of the random sheet.

When evaluating the mechanical and optical characteristics of a machine made paper sample, its properties relative to those of a laboratory sheet formed from the same furnish may be expressed as the *Forming Efficiency*

To improve *grammage uniformity*, the mix should be fed to the headbox directly after the dilution of thick stock with white water. No processes like screening or cleaning from which uncontrolled reject flows are drawn from the measured fibre flow should be allowed. Further, the material content in the recirculated white water should be controlled to a constant level if the composition of the paper produced is to be held constant.

In todays *headboxes*, the tapered manifold is the dominating method of distributing the mix flow into a tube bundle across the entire wire width. The distributing tubes can exhaust either into a stilling chamber, or directly into the outlet nozzle. In the latter case, the tube outlet area must be maximized to avoid excessive wake effects. Further, the nozzle *contraction ratio* must be large enough to reduce the degree of relative turbulence to an acceptable level.

There are two basic headbox designs for *stratified forming*. In one of them, thin, pointed vanes separate the different furnishes. In the other, thicker separation walls generate "air wedges", which may separate the furnishes all the way to the initial dewatering point. In the first case, layer mixing can begin before dewatering; in the latter case, four new interfaces between air and mix are created, and all are potential sources for disturbance generation.

Mathematical methods are now being applied to the calculation of water *flow patterns* in headboxes, which may eventually lead to designs with improved flow stability.

High consistency headboxes have been developed to form paper according to an extrusion process. To obtain acceptable mass formation, various channel shapes, causing mix deflocculation, are used.

Because of the complex interactions between dewatering forces, water flow, material movement and resulting web structure and elasticity, no models have so far been developed for the prediction of *filtration dewatering rates*. The Kozeny-Carman equation, describing flow through porous beds, is a too simplified model to be of any great value in this situation, and therefore empirical equations are applied instead.

The development of *forming wires* have lead to multi-layer designs where the topography of the paper and the wear sides can be optimized simultaneously.

For *Fourdrinier* dewatering, several new dewatering elements have been introduced, allowing a better control of the activity in the mix on the wire, and thus also of the mass formation.

Fourdinier dewatering can be especially sensitive to *pressure pulses* from the hydraulic headboxes since amplification due to standing wave generation on the wire can create considerable MD grammage variations.

Local slice lip adjustments, especially on hydraulic headboxes which normally have a low convergence nozzle, can cause considerable *cross flows* on the Fourdrinier wire, and this will have a large effect on the grammage profile. Further, local changes in fibre alignment will be generated, a problem which has not yet been given due consideration.

In *twin wire* forming, the dewatering pressure is generated by wire tension according to either of two basic principles: roll dewatering with constant; or blade dewatering with pulsating dewatering pressure. A combination of these two principles has resulted in the best mass formation and retention. Recently a new method has been demonstrated, in which the dewatering pressure is not generated by wire tension but instead can be controlled to the desired pressure event along the forming zone.

Transcription of Discussion

OVERVIEW OF THE PHYSICS OF FORMING

B. Norman (Review Paper)

Dr. C. Dunning, James River

I wonder if you can comment on how rapidly flocs form in the headbox. Let's presume for a moment that we have some means of destroying any flocculation at the entrance to the headbox. How rapidly would flocs form between the tube bank and the slice opening?

Prof. B. Norman

I know you can find figures in the literature on this subject, however I am reluctant to rely on them. For instance, Otto Kallmes presented a Table with figures showing how quickly flocs will reform at different consistency levels. In that paper he referred to Douglas Wahren. When I discussed this with Douglas, he did not agree with the interpretation put on his figures. His results were very specific and generalisations are not necessarily valid. Consistency level, degree of turbulence and geometry as a whole are variables which must be considered in reflocculation. Generally, there is adequate time for reflocculation. If you destroy the flocs at an early stage they can definitely re-appear later on. To break down fibre flocs you have to introduce turbulent energy and when that energy decays flocs re-form. This area will be explored further in tomorrow's papers.

Dr. H. Paulapuro, Finnish Pulp & Paper Research Institute

You did not mention retention at all in your review. We know that retention is related to the chemistry of the papermaking process but there are many physical effects also. Is there any specific reason why you did not mention this?

Prof. B. Norman

In this presentation I did not have the time, it is mentioned in the paper. It is impossible to make a good review without mentioning paper chemistry. One has to be careful when discussing retention as it must first be defined. In this paper what is referred to as first pass retention is a function of the ratio between the recirculated white water consistency and the headbox consistency. This is the term used in 99% of mills. This is useful only when considering one system where the white water distribution is kept constant. If you try to compare different machines it will be invalid because the only thing that is considered is what is going through the short circulation. There are examples of newsprint mills where half the fines in the thick stock are recirculated via the long recirculation system.It is not therefore correct to have a retention value which only considers what is going round in the short recirculation system. The major problem with the long circulation is one of time to equilibrium. We have simulated this and were also able to do measurements on a papermill together with IVL in Sweden. We changed the refining in a liner mill and wanted to see how long it would take the extra dissolved material to reach equilibrium. It took 48 hours for the long circulation. I am merely pointing out the complexities of the system and its bearing on retention. Details of retention will be covered in the Chemical Section later this week.

Dr. H. Paulapuro

May I continue with another question - could I have your opinion on the application of high consistency forming to low basis weight grades eg. below 100 g/m2.

Prof. B. Norman

If you design a new process it is much cheaper to choose a high consistency solution. Many components are not required at all and others are much smaller. HC forming will give some advantage for the product. Thus the advantage of using this technique in a board product comes from both capital cost reduction and product improvement. It is hoped that HC application will continue to lower grammages but the drive is not then as great as for board products. I think a more relevant question is on stratified production of low grammage papers. This is more important than high consistency forming of them.

Dr. G.A. Baum, James River

You implied that modern high speed headboxes with a jet to wire velocity ratio near to one could lead to instabilities in terms of the fibre orientation distribution. Could you comment on the contribution of automatic slice adjustments to that problem?

Prof. B. Norman

In devices with automatic slice flow adjustment you have to consider the influence of cross flow on the skewness of anisotropy, which has not been done so far. You cannot just control the grammage profile to what you want.

Dr. A. Ibraham, Papyrus, USA

I would like to understand more about your comments on contraction in the nozzle. If I understand you correctly are you in favour of reducing turbulence by increasing the contraction coefficient?

Prof. B. Norman

A higher nozzle contraction will mean a lower degree of relative turbulence which is an advantage in paper forming. It is particularly advantageous to have a perfect jet when you are considering twin wire forming.

Dr. A. Ibraham

In that case we are going to meet high L/b ratio. The jet is going to travel further down through the wire and it is going to flocculate further as shown by Kerekes. I am really against that concept. High L/b and low angle is not good for formation.

Prof. B. Norman

I am referring to the contraction within the headbox nozzle not the impact onto the wire. It is a function of flow velocity entering the nozzle and flow velocity leaving the nozzle. What you refer to is a separate topic.

Dr. M.B. Lyne, International Paper, USA

In your talk you were describing the sources of variation in orientation angle across the papermachine. Would you care to offer an explanation or a model for variations in orientation angle in the Z direction during forming? The difference in fibre orientation angle between the top and wire side of a sheet is an important factor in the complex curl of paper sheets.

Prof. B. Norman

The jet to web speed difference in a given CD position will gradually decrease as dewatering proceeds. The original cross flow component in the same CD position will, by definition, move sideways during dewatering, and thus successively influence other CD positions.

Dr. M. MacGregor, KTH (Voith), Sweden

Is the non-uniform shrinkage which occurs during drying and the need to have uniform basis weight possible to optimise, or does it lead to a compromise situation?

Prof. B. Norman

It is theoretically impossible to have both uniform orientation and grammage in the cross direction if you have non uniform cross machine shrinkage.There is a paper later this week which says how you can restrain the paper to avoid shrinkage in the cross direction during drying

Dr. M. MacGregor

If basis weight control is by flow redirection, then I agree - which it is in most cases.

Prof. B. Norman

Unless you control local consistency in the headbox which is a theoretical solution. When you control grammage with slice opening the aforementioned problems are always present.

Dr. M. MacGregor

So in general the papermaker does not realise that he is giving up many things to achieve a nice flat reel.

Dr. T. Uesaka, PPRIC, Canada

In one of your slides you mentioned the tensile ratio between MD and CD as a function of jet speed and wire speed ratio - I understand this relationship looks very unique when we keep the contraction ratio constant. I am wondering if we increase the wire speed by keeping the jet speed and wire speed difference constant what will happen to that relationship. We have already experienced in many high speed machines that we have a difficulty in controlling the tensile ratio by changing the jet speed/wire speed difference in contrast to the older Fourdrinier machines.

Prof. B. Norman

What do you mean by high speed machine? Is it a Bel-Baie?

Dr. T. Uesaka

Yes, in the case of Bel-Baie for example.

Prof. B. Norman

This is another project we are working on. In the case of the Bel-Baie you haven't the same degree of control as you have on a Fourdrinier or Roll-former because all the pressure pulses during dewatering will effect the fibre orientation. You can only control the jet conditions as it enters between the two wires.

Dr. R. Ritala, Finnish Pulp & Paper Research Institute

I would like to ask about fibre flocculation. The Wahren-Meyer formula has been derived so that we have three contact points on the average for each fibre. Why should this have any significance as it is on average, I can understand why we need three points to build flocs but why do we need three points on the average?

Prof. B. Norman

I refer you to Dr. Wahren.

Dr. R. Ritala

I would like to offer an alternative explanation. There is a coincidence in that the threshold to have a connected network of fibres (That can be shown to be at a consistency which is simply the inverse of the fibre aspect ratio) in fact fits the data in your Fig.3 a bit better in the region from 80 - 200 in the aspect ratio.

Prof. B. Norman

Yesterday you mentioned this new reference from a physics paper to me. This will be interesting to see. It would simplify things if the sediment consistency is equal to the fibre diameter divided by the fibre length.