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PRINTING INK PENETRATION INTO THE STRUCTURE OF PAPER

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THE quality of a printed product can in many cases be controlled if the extent of liquid penetration into the sheet structure and the various parameters affecting it are well known. There is, however, a lack of a sufficiently sensitive method for the determination of minute amounts of ink in the sheet and this makes studies on the interaction of paper with ink difficult.The approach to fill this gap, described now, consists of the determination of the ink concentration profile across the thickness of a paper after application of radioactively labelled ink on one side and stripping ultra-thin sections from the opposite side of the paper.

The ink used was IPI flatbed news black and was mixed with ^{14}C-labelled stearic acid to an activity of 70×10^8 counts per min per g of ink. The pure vehicle was also labelled in the same manner.

The printing of weighed and conditioned paper strips was made on the IGT A1 printability tester. The strips were again weighed after printing and the printed area measured planimetrically on an enlarged image of the printed spot.

Stripping—Serial fibre layers were removed from the test sheets by first applying a piece of adhesive tape with uniform pressure to the unprinted side of the paper. The trimmed strips were placed in vials filled with liquid scintillator solution composed of reagent grade toluene as a solvent, 4 g/litre PPO (2,5-diphenyloxazole) as a primary scintillator and 100 mg/litre POPOP [1,4-*bis*-2-(5-phenyloxazolyl)-benzene] as a secondary scintillator.

Counting—The samples were counted with a Packard 3375 automatic liquid scintillation counter equipped with three channels. This is a very sensitive counting method (much more so than by the Geiger-Müller detector), allowing the counting of radioactivity of low energy beta-emitters like ^{14}C.

Under the chairmanship of Dr J. A. Van den Akker

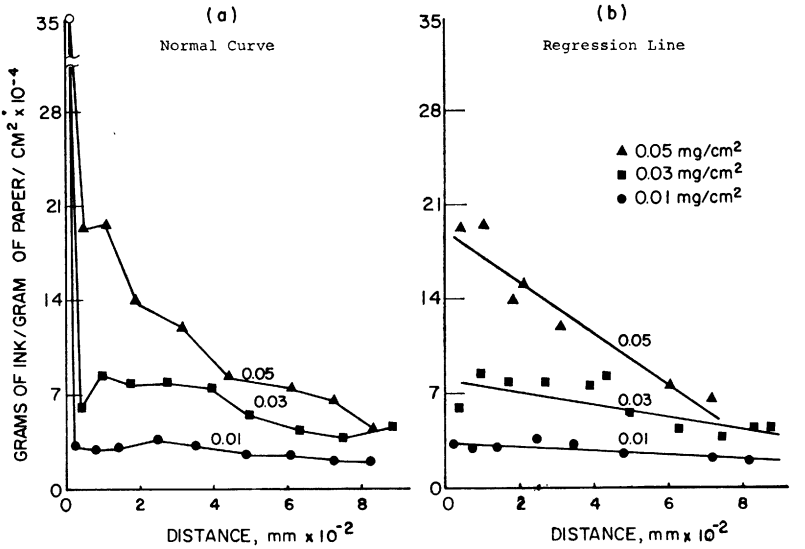

Fig. 1—Distribution of ink through the thickness of newsprint S for different ink coverage levels: printed on wire side

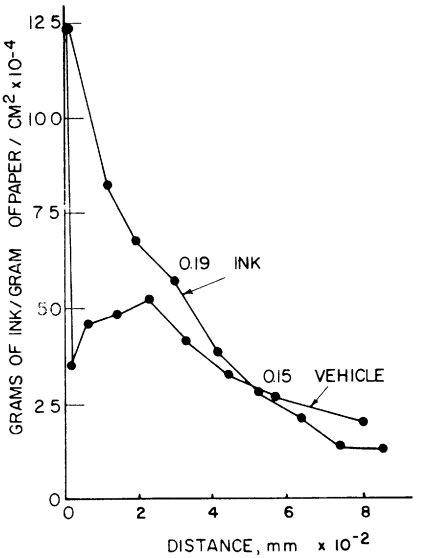

Fig. 2—Distribution of ink and vehicle through the sheet thickness of newsprint S: printed on wire side

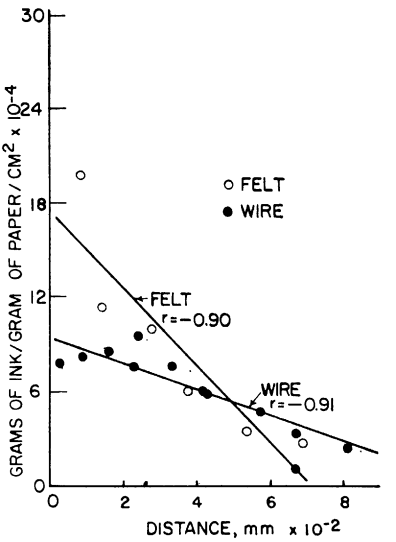

Fig. 3—Ink penetration on wire and felt sides of newsprint 11 (0·03 mg of ink/cm²)

The resulting count rate for each stripping divided by the weight of that stripping, then divided also by the area of the printed spot is plotted against its respective location in the original paper to obtain the ink content profile across the sheet thickness.

Plots of ink profile—Fig. 1 is a sample plot of the amount of ink as a function of the distance from the printed surface of the paper. The first point indicates, as expected, that the printed surface strip contains the largest fraction of the ink. Immediately below the printed side, an abrupt drop in the curve is observed and thereafter the gradient of ink concentration is much smaller throughout the rest of the paper thickness.

The 'horizontal' part of the curve exhibits a pronounced waviness, which probably originates from the unevenness in the thicknesses of the internal layers of the sheet (due to flocculation, etc.). Therefore, a linear regression was applied to all the data for individual strips exclusive of the surface point. This linear regression represents the 'averaged' profile of the ink in the sheet and its gradient of penetration.

A pronounced minimum in the curves of ink distribution, followed by a maximum, across the sheet thickness almost occurs immediately below the surface of the sheet. This minimum indicates the presence of a low density (high porosity) layer in this position. The ink or vehicle would pass through this sub-surface layer and be retained on the layers below (maximum in curve). Leaving this central region of the sheet, the ink (vehicle) concentration gradually decreases when excess ink is applied, the minimum does not appear, since the vehicle carries the carbon particles with it into the sub-surface cavities.

The method was used to compare the movement of ink with that of vehicle through the paper cross-sections, differences in behaviour of felt and wire side, movement of ink in lightweight papers compared with that in heavier papers, etc. and examples are shown in Fig. 2 & 3.

The method was also successfully used to determine the penetration and distribution of phenolic (and other) resins through the thickness of saturating base papers.

Discussion

Mr G. F. Underhay I believe that, in our printability discussions, we have rather forgotten some of the good work that was done 10 or more years ago. I would like to refer especially to a paper by G. L. Larocque (*Pulp & Paper Mag. Can.*, 1967, **68** (1), T16) of the *New York Daily News* and formerly of PPRIC. Gerry was very down to earth and, as I remember his conclusions, he hardly mentioned things like tear, tensile and burst. Instead, based on 20 years of detailed records, he showed that satisfactory runnability was linked with good stretch characteristics, better winding, higher moisture content, minimum roll damage and low shive content (consequent upon improved shive removed facilities in the papermills). Thus, he moved substantially away from tests on ridiculously small bits of paper, which may well be completely unrepresentative; he studied whole rolls rather than square centimetres. How otherwise can you spot a single shive or other potential fracture points as being likely to cause a break in several miles of paper? (For further comments and references, particularly to George Sears, see my paper 'Mechanical Pulp —the Neglected Gold Mine', *Tappi*, 1968, **51** (9), 39A.)

Dr L. S. Nordman Prof. Renata Marton did not mention the time lag between printing and splitting of the sheet of paper. It must have a profound influence on the appearance and situation of the maximum value, because we have found that there is a marked redistribution of the vehicle in the sheet when the time after printing increases.

Prof. Renata Marton We did not split right away after printing, because it is impossible to split 14 or 15 layers very fast, though we consider the time to be very important. We have not yet determined how long the vehicle continues to migrate, but we intend to do so. The time between printing and testing was about 15 min.

Dr J. Marton As Mr Underhay has already mentioned, the runnability of newsprint is more affected by mechanical condition of the roll and by the

moisture content than by some other fundamental paper properties like tear or smoothness. Nonetheless, printability problems are quite important for other categories of paper like fine papers coated or uncoated used for more quality printing. We should not therefore consider everything from the point of view of newsprint.

Dr J. Grant I am not quite clear how Prof. Marton's method, which intrigues me very much, differentiates between the progress of the pigment and the progress of the ink vehicle through the thickness of the paper. One illustration showed both as separate curves; but, if she activates the ink as a whole, how is one distinguished from the other?

I would like to add a few remarks of a general nature, which suggest themselves to me as a result of listening to the papers this week.

I am all with George Underhay in that we should try to keep our feet on the ground in the practical applications of the knowledge that we are hearing about, although this symposium is of course concerned with the fundamental properties of paper as distinct from their immediate practical use.

I have always regarded paper as having properties in equilibrium. Thus, when you attempt to improve one property, you invariably lose on another. The simplest example I suppose is the one I mentioned the other day—when one beats pulp to improve strength, one loses opacity, dimensional stability and one can give many other examples. So the problem really arises how can we take this welter of complicated factors that go to make up good printability or runnability and find optimum compromise among them all to give the best results on the papermachine.

My suggestion is of course not original—I know that it has been applied, especially in North America. I refer to furnish optimisation, which I believe is the real answer to the practical application of these recondite properties. I have carried out large-scale experiments on this and was very impressed by the results obtained by feeding into a computer the desirable characteristics from a number of different pulps—hardwood pulps, long-fibred pulps and others—and programming the computer to give the proportions that we should use and how we should treat the pulps in order to obtain the best combination of printing characteristics. I believe that this is really going to be the best way of achieving something practical out of the theory that we have heard during the course of this meeting.

Prof. Renata Marton I was rather expecting this question. We were unable to provide specific information about the distribution of the radioactive tracer between the carbon black and the ink. We are working on this now, but we assumed equal specific activities of the carbon black and the ink vehicle. We

know, however, that errors are introduced by this assumption, but they should not affect the qualitative conclusion I have presented.

Dr J. Grant The difficulty is that the vehicle and the carbon black travel through the paper at different rates and to different extents. Unless you separate their effects, the results are really meaningless.

Prof. Renata Marton Observation under the microscope of each layer helped to establish where the carbon stopped and how the vehicle continued to migrate. I presented a few examples of what we are doing, but the work is not finished and we hope greatly to improve on this promising method.

Mr R. Rahkonen I would like to add one point that might be of interest. I think it might be possible separately to label the pigment and rhe vehicle with two labelling substances having different spectra of radioactive radiation. Then it should be possible using Prof. Marton's technique to measure separately the amounts of pigment and vehicle in the different layers of the paper simply by measuring the intensity of radiation at two different wavelengths. At Rauma, we have used the same technique to measure separately the flow of wood chips and of coating liquor in a continuous digestion system.

Mr J. R. Parker May I ask Prof. Marton how her work compares with that by Larsson, who has used similar techniques?

Prof. Renata Marton Yes, we know of Dr Larsson's work very well and we co-operate closely. He uses a Geiger-Müller counter, which is much less sensitive than a liquid scintillator counter, for this counts a hundred times less radioactivity than a Geiger-Müller counter. Our curves are similar to some extent, therefore, but we regard the scintillation method to permit much greater precision, since we can detect parts of milligrams of ink in each layer.

Dr A. B. Truman It is intriguing to think that one might be able to feed into a computer the basic physical data on paper properties to obtain from it the desirable printing characteristics of the sheet (which I would suspect are very difficult to define).

In my opinion, the problem is more educational than technological. The papermakers must be educated to make a consistent product with controlled properties and the printer must learn to use the paper in an intelligent way. I can cite an example of a troubleshooting job that I went on recently; a printer of newsprint had had considerable web breaks on his machine. On questioning him closely, I discovered that the firm had recently installed air

conditioning equipment that considerably reduced the ambient moisture content. I explained to him the relationship between that and paper properties, the tensile strength and stretch—and really that in itself was the solution to the problem.

However erudite our study of the factors contributing to good printability and runnability, the effort will be to no avail if we do not communicate effectively with the papermaker and the printer.