# VIRTUAL REALITY SHEET FORMATION AND PRINTING (COMPUTER PROGRAM)

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Abstract: Previous research work[1,2] has demonstrated that print quality can be influenced by the density variations in the base sheet of paper. These, in turn, are affected by the length of the fiber in the sheet, and by the hole sizes in the filtering media used to form the sheet.

A computer program, Fibremat™ [3], has been developed to enable us to better understand the fundamentals of interaction between the fibers and the drainage through the holes in the filtering media. This program simulates the formation of a sheet of paper under specified conditions. It is further designed to simulate the effect density differences in the sheet have on final print quality.

Density differences in a sheet of paper will directly affect the rate of absorption of printing ink into the paper. The rate of absorption has a direct bearing on the paper's print quality through surface gloss, half tone dot gain, print strike-through, and the tendency for offsetting and rub-off. The density differences in the paper can be caused by large scale flocs, which can easily be seen with the naked eye, or by micro scale density differences, which can be seen with 5X magnification. This paper deals mainly with the micro scale density differences affecting the absorption rate, and hence quality of areas equivalent to that covered by 1 to 5 half tone dots - depending on the printing screen used. It has been concluded from previous work, that the judgment of print quality, used by printers and advertisers, in fact is an initial assessment - especially in the half tone area - of the quality and uniformity of each half tone dot, one to another, and then further expanded to the whole image. Variations in gloss, dot size, etc., resulting from variations in ink absorption, will be objectionable to both the printer and advertiser.

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KAJAANI FS-200
RAW RESULTS

| | | | |
|---|---|---|---|
| SAMPLE TITLE | | 70%SGW 30%KRAFT | |
| SAMPLED | | 30-01-91 | |
| ANALYZED | | | |
| UPPER LIMIT | | 7.2 | MM |
| LOWER LIMIT | | 0 | MM |
| ARITHMETIC AV | | 0.21 | MM |
| TOTAL FIBERS | | 37542 | |
| LENGTH 0.20 MM | P= | 63.93% | |

POPULATION DISTRIBUTION

| LENGTH | | FIBERS | DISTR% | CUMUL% |
|---|---|---|---|---|
| 0.00 | 0.05 | 4759 | 12.68% | 12 68% |
| 0 05 | 0.10 | 9447 | 25.16% | 37 84% |
| 0.10 | 0.15 | 6254 | 16.66% | 54.50% |
| 0.15 | 0.20 | 3541 | 9.43% | 63.93% |
| 0.20 | 0.25 | 3002 | 8.00% | 71.93% |
| 0.25 | 0.30 | 2252 | 6.00% | 77.93% |
| 0.30 | 0.35 | 1453 | 3.87% | 81.80% |
| 0.35 | 0.40 | 1000 | 2.66% | 84.46% |
| 0.40 | 0.45 | 843 | 2.25% | 86.71% |

Figure 1. Kajaani Optical analysis of fibrous material.

The fibrous material used to form a sheet of paper will vary in length depending on many factors, such as; whether it is virgin stock or recycled, the geographical location of origin of the virgin fiber, the pulping process used, and any use of non-fibrous fillers - such as clay. An instrument has been developed which optically measures and computes the lengths of the fibers used to form a sheet of paper. This instrument, the Kajaani™ FS200 Fiber Length Analyzer, is being used in this work. Figure 1 is a copy of a print-out of an analysis conducted on the fibrous stock used to form the sheets of paper, actual and simulated, illustrated in this paper. Take note that 63.9% of the fibers used to form these sheets of paper are less than 0.2 mm long, and 86.6% are less than 0.4 mm.

Figure 2 shows the computer generated images of the holes in the two filtering media used to form the two sides of the twin wire formed sheet illustrated later in this paper. Fiber lengths of 0.2 mm and 0.4 mm are shown to scale, in Figure 2, and compared to the hole sizes found in each of the two filtering media. It should be pointed out that the two filtering media illustrated here are very fine compared to those used in earlier years. As new materials and technology become available, the filtering media will obviously become finer still, as logic would predict when looking at this figure. Filtering of these very short fibers, and the formation of a mat, does not occur until some of the longer fibers have bridged the holes in the filtering media, thus forming smaller holes. The considerable flow of water through these holes, and the resulting turbulence, together with the short, fibrous material, creates micro density differences in the sheet of paper. This, in turn, affects the rate of ink penetration.

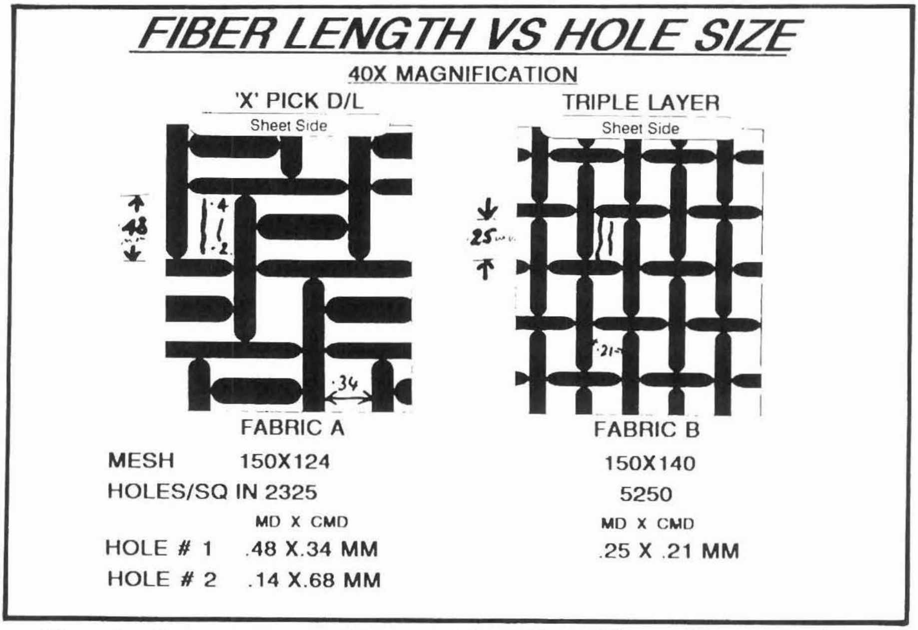


Figure 2. Computer generated images of the surface of the two forming media used in simulation and reality.

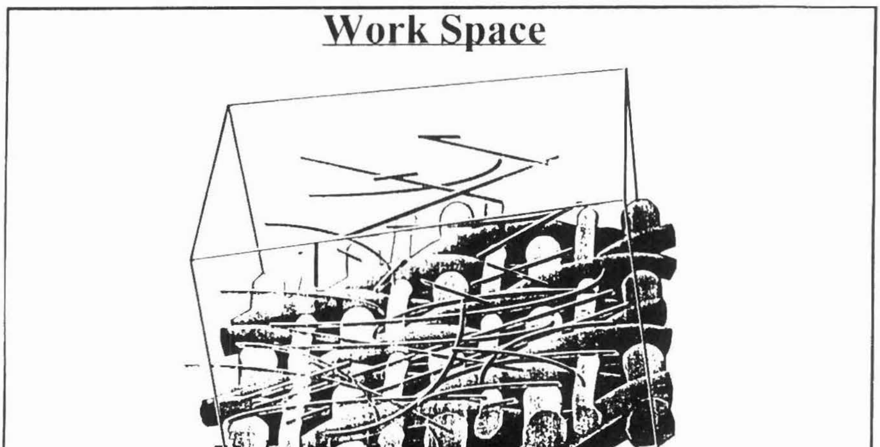


Figure 3. Fibremat™ program creates a 3-D Matrix memory.

Required Inputs

The required inputs for the Fibremat™ program are: The filtering medium surface topography, the fiber length distribution from a Kajaani analysis, the sheet basis weight and anisotropy, the fiber coarseness and aspect ratio, and the drainage forces on the paper machine. Once the simulation parameters are established, the program creates a 3-D matrix in memory where the fibers are dropped, as shown in Figure 3.

Program Sequence

The program sequence is described below:

1. Fiber Selection: Each fiber is picked randomly from the stock defined by the Kajaani data.

2. Fiber Orientation: Both machine (lengthwise) and Z (vertical) orientation are selected from a choice of options; from totally random to a definable bell curve shape.

3. Fiber Location: The location where the fiber is dropped is based on the most probable flow path around the mesh. This statistical function changes every time a fiber bridges a hole in the filtering medium, and it also changes as the fiber mat is created.

4. Fiber Retained Conditions (Whether the fiber is held by its center, with the exception of fines, or whether two contact points are present on the two sides of the center of the mass): In order to take into account the flexible nature of the fibers, the fiber length is modified, using a function that computes the proportion of the fiber that must be supported in order for it to be retained.

The program will repeat those steps until the final basis weight is achieved, and a series of reports on the sheet is produced. These reports include a see-through view, a glancing light view, the detailed composition of the sheet and the white water, the first pass retention, the complete position and location of every fiber in the sheet, and the impact of ink show-through in printing, where relevant. The results are mostly qualitative, but they can be post-processed by an image analyzer to extract information on formation quality, density variation, printability or pin-hole tendency, depending on the final product.

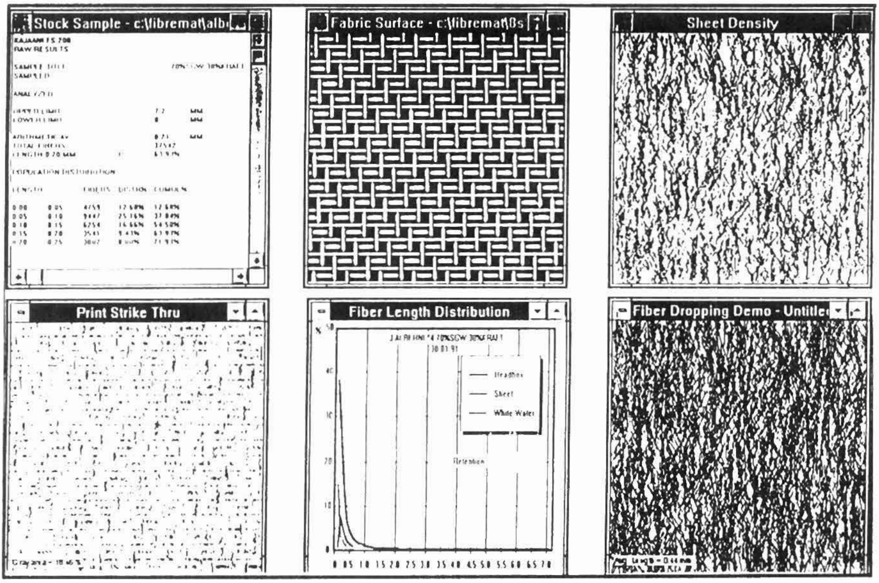


Figure 4. Computer generated files of simulated run on surface A.

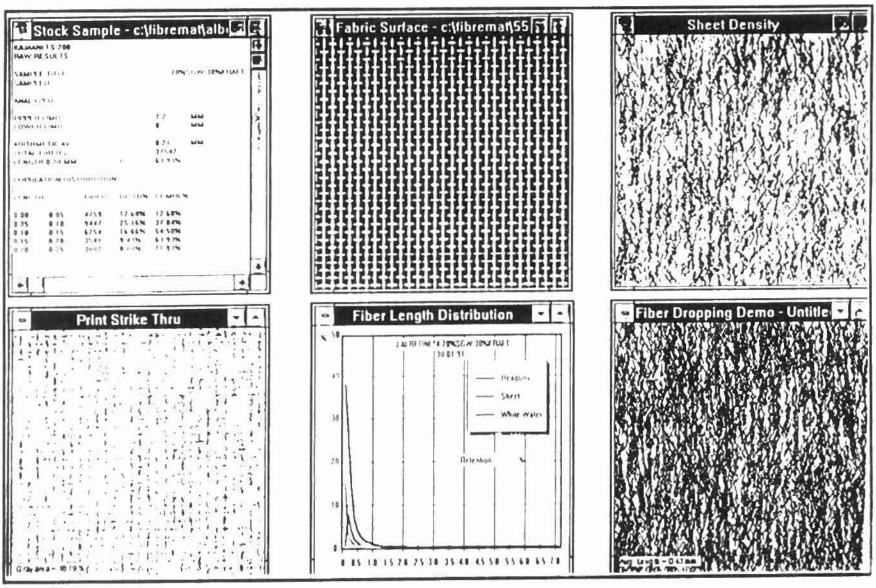


Figure 5. Computer generated files of simulated run on surface B.

Using the Kajaani fiber length analysis shown in Figure 1, and the two filtering media structures shown in Figure 2, the Fibremat™ program was used to simulate the formation of a sheet of paper on a Twin Wire paper making machine. Since the final sheet of paper will have two sides formed by two different filtering media, the two sides will have different micro density difference characteristics, although they are made from the same fibrous solution, and they will print differently. The files generated from these two simulations are shown in Figure 4, for side A, and in Figure 5, for side B. Since this paper and presentation are aimed at printers, we will ignore those files which give information to the manufacturer of the sheet of paper, and concentrate on those that relate to the quality of the final print.

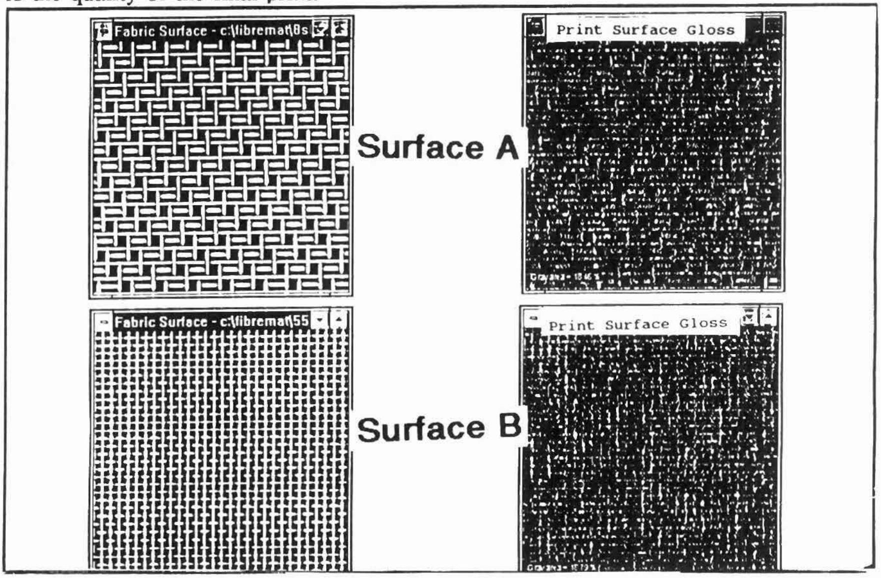


Figure 6. Simulated print gloss patterns corresponding to density differences caused by the forming media on both sides.

As stated earlier, prior investigation has shown that print quality is dependent on the micro density differences in the sheet. Figure 6 shows the simulated, predicted, print gloss pattern corresponding to the density differences created by the two filtering media on the surfaces of sides A and B, using the same fibrous solution. It shows that in the area of the sheet formed over the holes in the filtering medium, there is a high density compared to the density in the area formed over the knuckles that surround the holes. This high density has resulted in the ink staying up on the surface of the sheet, giving high gloss, when a uniform layer of ink is laid on the surface of the sheet (complete 100% coverage). In the areas of low density, formed over the knuckles, the ink has penetrated into the sheet, resulting in less gloss. In extreme cases, a fine pattern can be seen in the gloss, on the surface of the sheet. This pattern reflects the mesh of the filtering medium, as can be seen in the computer simulations of both sides of this single sheet of paper.

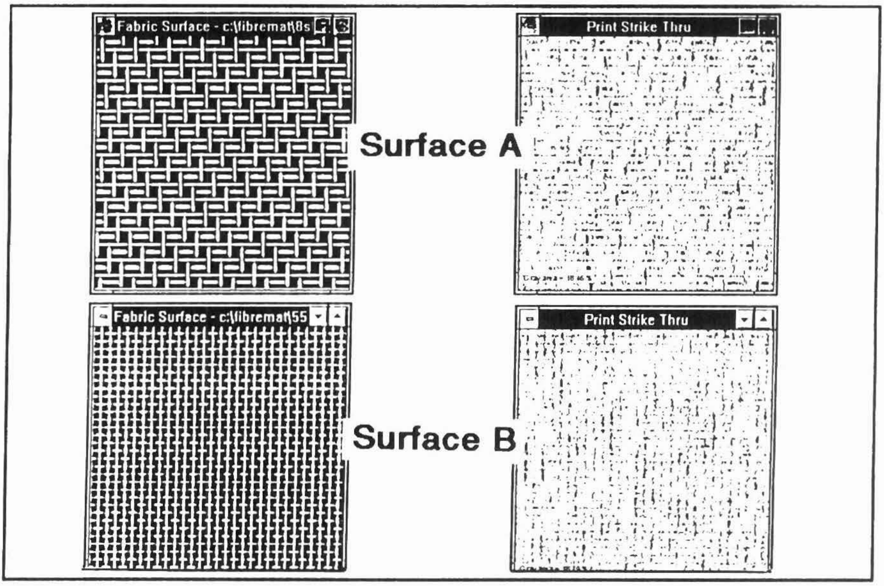


Figure 7. Simulated print strike-through patterns corresponding to density differences caused by the forming media on both sides.

Figure 7 shows the simulated effect of ink strike-through to the opposite side of the sheet to which the ink was applied. In this case it shows how the ink penetrates to a greater degree in the low density areas of the sheet, i.e. the areas formed over the knuckles of the filtering medium.

The results in both Figures 6 and 7 show that, as the surface of the filtering medium becomes finer, with more uniform holes, so the print quality becomes more uniform in both surface gloss and lack of print strike-through.

All the previous examples have been from the computer simulation, using the Fibremat™ program. Figures 8A and 8B show the results that were experienced in reality, using the fibrous solution shown in Figure 1 and the two filtering media shown in Figure 2, on a Twin Wire paper machine making base stock for flyer printing. Figure 8A shows the print quality on the printed surface of each side of the sheet, and Figure 8B shows the print-through, or penetration of the ink into the center of the sheet. From these two illustrations of the final print, on the actual sheet produced on these two, quite different, filtering media, it can be seen that the density differences created in the sheet of paper, directly affected the rate of ink penetration. And the variations in rates of ink penetration, in turn, affected print quality through both gloss and strike-through.

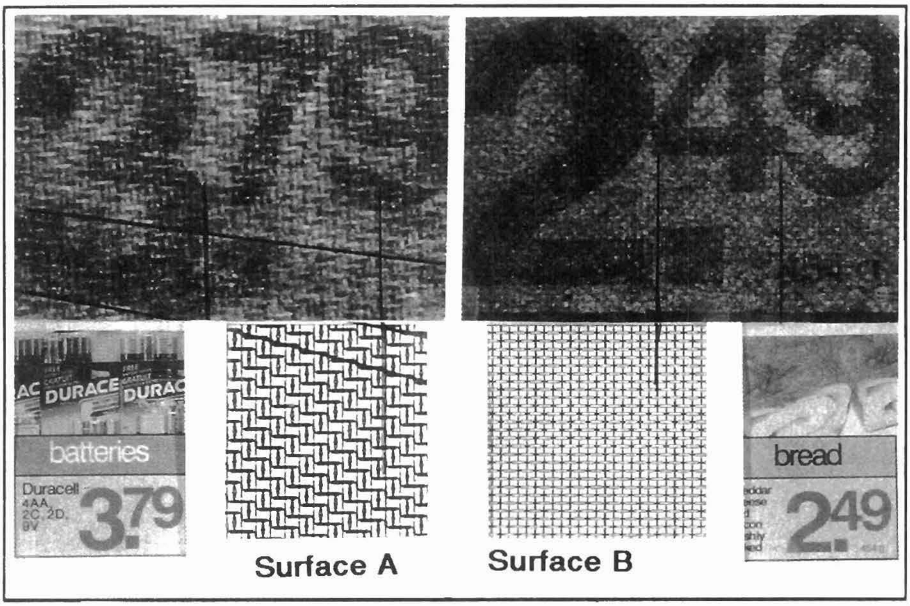


Figure 8A. Actual results obtained in reality showing print gloss on both surfaces.

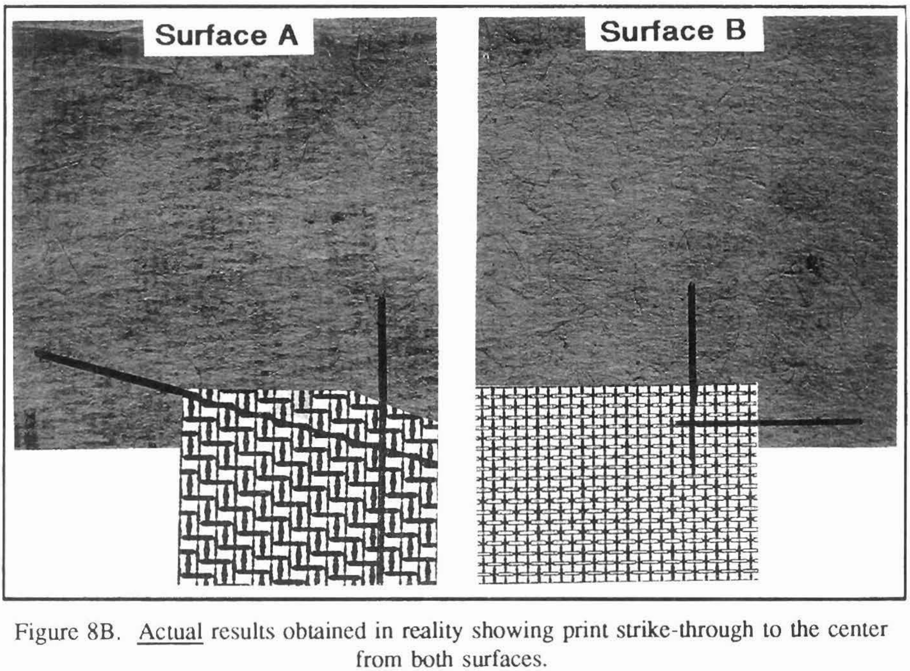


Figure 8B. Actual results obtained in reality showing print strike-through to the center from both surfaces.

When one compares the Fibremat™ computer generated virtual reality results shown in Figures 6 and 7 to the actual results shown in Figures 8A and 8B, it can be seen that we have come a long way in reproducing, in the computer, what will happen in practice. The program has allowed us to predict the quality of sheets produced with different filtering media designs, using numerous fiber length combinations. From this we are able to predict print quality when using 100% ink cover. We are now working on a project which will relate half tone print quality to the micro density differences caused by varying the filtering media and fiber combinations.

The ultimate aim of our work is to extend the virtual reality capabilities of Fibremat™ to the whole spectrum, from raw material selection to the final printed product, for all grades of paper and all printing processes.

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[1]Danby, R. The impact of multilayer fabrics on sheet formation and wire mark. Pulp & Paper Can. 87(8): T309-314 (Aug. 1986).

[2]Danby, R. The influence of fabric structures on the two sides of sheets produced on twin-wire and hybrid formers. Pulp & Paper Can. 90(2): T45-52 (Feb. 1989).

[3]Bouchard, A. Computer simulation of formation with Fibrematt 3.0. Presented Feb. 1, 1994 at CPPA conference, Montreal, Que., Canada. Published in conference proceedings for the above conference.