Moisture Profile Control with Hydraulic Spraying Nozzles

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ABSTRACT

Successful moisture profiling depends on nozzle technology. This paper describes an extensive range of tests on the performance of hydraulic nozzles spraying on the paper. The spray patterns can be adjusted for the control of their overlapping by the water pressure, orifice size and geometry, nozzle spacing, and the location of the nozzle from the paper.

The particle size produced by a spray is dependent on capacity, spray angle, pressure, type of nozzle, and properties of the liquid being sprayed.

Particle size increases with increases in flow rate of the nozzle and decreases with the increase of pressure. The wider spray angle produces smaller particles in that the web is spread out more and the tendency is for a finer break-up. Extensive tests were done on various type of hydraulic nozzles for their characteristic performance. The type of spray pattern also effects the particle size. The flat spray type gives fine particle comparing to the full cone type which has a coarse break-up. A solution sprayed through a nozzle divides into droplets that are spherical or nearly spherical in shape. A recognized measure for indicating the size of these droplets is micrometers.

Droplet smaller than 100 micrometers are considered highly driftable and are so small they can not be readily seen unless in high concentrations. Adjusting the nozzle parameters for a correct particle size is necessary. Too small particles will not have enough momentum to get through the air boundary layer built near the paper surface and too coarse particles will generate scattered profiles due to local concentration of the particles.

Pictures are taken from hydraulic nozzle sprays using the university of British Columbia's equipment. A triple-pulsed spark gap flashes with a flash duration of 700 nsec measured by a 150 MHz photodetector was utilized. The energy produced per flash is several Joules. Argon gas fills the spark gap to produce more predictable and brighter flashes. These pictures can be analyzed for the particle size and momentum of the particles.

A computer program was developed for the analysis of the hydraulic nozzle patterns. The program determines the best nozzle spacing and nozzle distance from the paper in order to have a controllable profile with low percentage coupling.

1. Introduction

Conventional papermaking machinery for producing a continuous sheet of paper includes equipment to set the sheet properties of the paper as it is being manufactured. Generally, on-line measurements of sheet properties, such as thickness, moisture, gloss or smoothness are made by scanning sensors that travel back and forth across the width of the sheet of paper in the cross-machine direction (CD). The scanning sensors are located downstream of actuators that are controlled to adjust the sheet properties. The scanning sensors collect information about the sheet and provide control signals to the appropriate actuators to adjust the profile toward a desired target profile in a feedback loop. There are two predominant remoisturizing system in used today, air atomized and hydraulic atomized nozzles, that both rely on water spray nozzles positioned along the cross-machine direction.

Flow Rate Setpoints (%)																
100																O
93.33															O	
86.67														O		
80.00													O			
73.33												O				
66.67											O					
60.00										O						
53.33									O							
46.67								O								
40.00							O									
33.33						O										
26.67					O											
20.00				O												
13.33			O													
6.67		O														
0	O															
Nozzle A	X	O	X	O	X	O	X	O	X	O	X	O	X	O	X	O
Nozzle B	X	X	O	O	X	X	O	O	X	X	O	O	X	X	O	O
Nozzle C	X	X	X	X	O	O	O	O	X	X	X	X	O	O	O	O
Nozzle D	X	X	X	X	X	X	X	X	O	O	O	O	O	O	O	O

Nozzle on O / Nozzle off X

Fig. 1

Hydraulic nozzles produce a flat spray that delivers water in a generally elliptical pattern. Conventionally, the system employs 4-bit logic so that 16 different water flows are possible for CD profile zone by various on/off combination of the nozzle control solenoids.
Hydraulic atomized system also generally consist of a boom extending in the cross-machine direction, however, each profile zone is conventionally defined by 4 nozzles producing discrete, flat fan sprays that overlap without intersecting. CD moisture profile zone width is variable down to 50 mm with 100 mm being the most common spacing.

2. Apparatus

The design for the test apparatus consists of an inclined trough table, collection tube rack, manifold and support rack for spray blocks, solenoid control panel, booster pump, pressure regulator and pressure gauges (see Fig. 2). This system allows for changes in height from 2” to 15” from the trough table and 34” of CD travel above the table. The trough table consists of 95, 5/16” slots cut on 3/8” centers into two 18”x24”x3/4” acrylic sheets forming a fluted surface 36” wide by 24” deep. Water landing on the trough table runs down the fluted inclined surface into 3/8” IDx11.5” long, clear acrylic collection tubes positioned at the bottom edge. Up to 5 spray modules can be mounted to the support rack and manifold and be positioned any where above the trough table. The data gathered is the measured height values of the water collected within each tube of the test rig and is related to the shape of the spray distribution pattern that is produced by the nozzles.

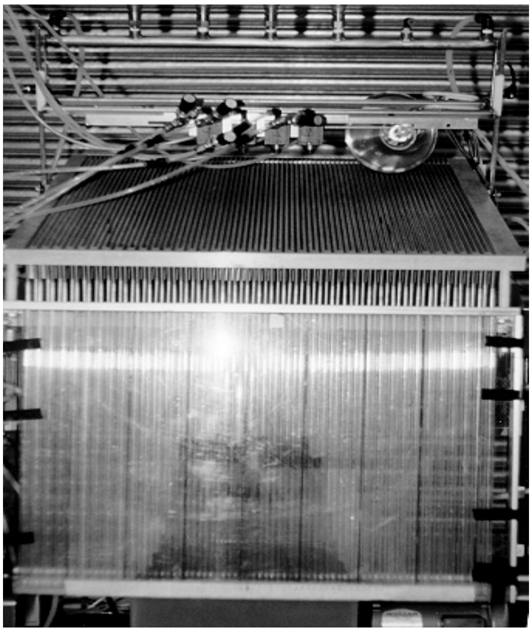

Fig. 2 Test-Rig

Spray distribution tests were conducted on a test rig that consists of tracks spread along the platform of the test rig, the platform represents the CD width of the paper. Water spread onto these tracks will get collected in the acrylic tubes below. These tubes collect the volume of water which accumulates after one spray test. The tubes filled with the water show the spray distribution pattern which related to the amount of water collected along the CD width of the paper. Tests are conducted for each of the different types of commercially available hydraulic nozzles and the data collected is inputted into the *Spray Distribution Analysis* program for analysis.

3. Results and Discussion

3.1 Spray Profiles and Particle Sizing

A common concern of papermakers is dry edges. This often necessitates overdrying the sheet to maintain acceptable moisture variation (peak to peak), but this action limits productivity. It also damages physical strength by frying the fiber and embrittling the bond. Remoisturizing has, for many years, been found to combat this condition.

The smaller the spray particle size, the more surface area it offers, which leads to better distribution and absorptivity. Modern remoisturizing system can achieve 50-100 micron mist without the use of supplemental compressed air.

Particle sizing tests were done using high speed photography techniques. Equipment for these tests were borrowed from the University of British Columbia . An expensive high speed flasher was used in conjunction with a timing control board and a camera to take high speed pictures of the sprays discharged from several commercially available hydraulic nozzles (see Fig. 3 as an example). The timing control board synchronized the camera with the flasher. The results were still pictures of sprays at different water pressure for various nozzles. From the pictures taken, the spray angle and individual particle size could be observed. The actual size and momentum of the particles could be measured by digital image analysis software.

Determining the size of the spray particles is important in calculating the momentum of the particles as they reach the paper web. They must have sufficient enough momentum to reach the web as well as be able to be absorbed by the paper. The bigger they are, the greater the momentum, yet the smaller they are, the better the absorption rate.

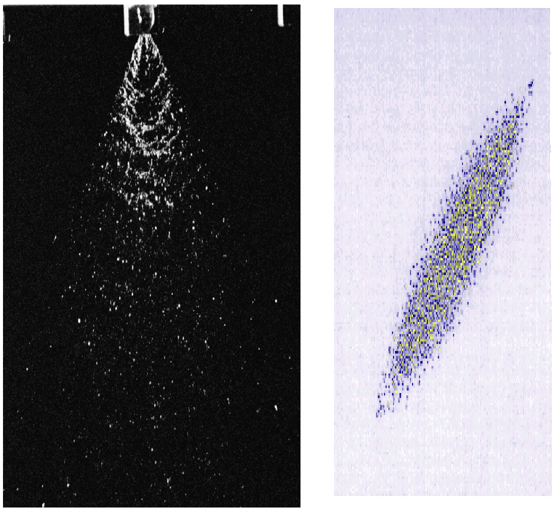

Fig. 3

A picture of a spray discharged from a commercially available hydraulic nozzle, at 60 psi water pressure. The spray angle of 65 degree is obtained with a flat fan shape of spray on the paper. There are many theories to predict the spray patterns of a nozzle. Many different conditions a nozzle might be subjected to. Thus the need of these theories are only aided by the many diverse testing equipment and technique. It usually takes more than one method to find the overall characteristics of a spray. It all depends on the importance of what has to be analyzed. The photographic method used in the analysis of these nozzles was sufficient in determining its performance in the remoisturizing field of the paper

3.2 Controllability of the moisture profiles

For controllability of cumulative moisture profile, it is desirable that the following guidelines be met:

1. The peak to peak values of the cumulative moisture profile must fall within 10 % of each other.
2. There must be only 1st coupling between the sprays from adjacent nozzles.
3. The volume of spray from one nozzle defining a particular profile zone must not differ more than about five percent from the volume of the overall spray within that zone (overall coupled and uncoupled volume within the zone).
4. * There must not be more than 10% first coupling between the sprays from adjacent nozzles.

* individuals define coupling in different ways. For example, in our case, % of coupling is defined as;

$$\text{\% of coupling} = \frac{\text{coupled volume within the zone}}{\text{total volume within the zone}}$$

A computer program was developed that calculates the % of coupling and predicts the best nozzle spacing and nozzle height from the paper, for a controllable % of coupling. You can see the graphical meaning of this % value in Figure 4. This will be defined, because there will be discrepancies in the way different individuals define this term. Because of this discrepancy, we have included three more visual facts to specify industry standards as shown above. These extra criteria assure the controllability of the spray to a higher extent.

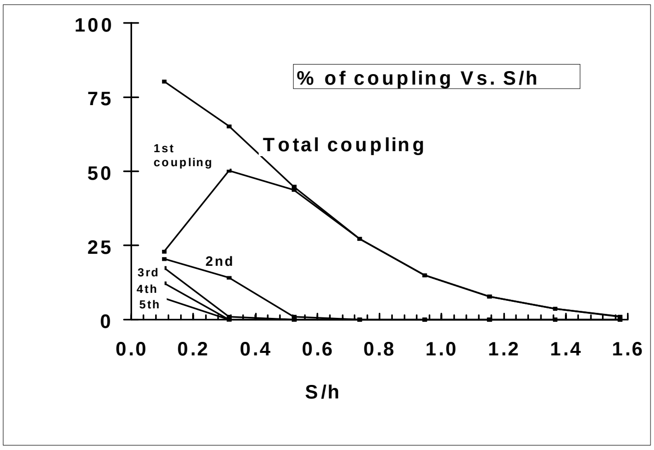

Fig. 4
Graph of % of Coupling
The % of coupling are prepared and plotted as % of coupling versus the nozzle spacing normalized with the stand off distance of the nozzle from the sheet. In this graph the 1st, 2nd, 3rd, 4th and 5th couplings are displayed and we would like to be in the spacing falling into only 1st coupling. This will assure a controllable spray.

3.3 Spray Distribution

Nozzle spacing and distance from the paper sheet also affect the percentage of coupling and the width of the spray distribution. A moisture profile with a high percentage of coupling is not controllable. A viewer of the spray distribution obtained from one of the commercial hydraulic nozzle shown in figure 5 indicates that nozzle does not meet the above given criteria. Although there is only the 1st coupling of adjacent nozzles, but peak to peak is %45.

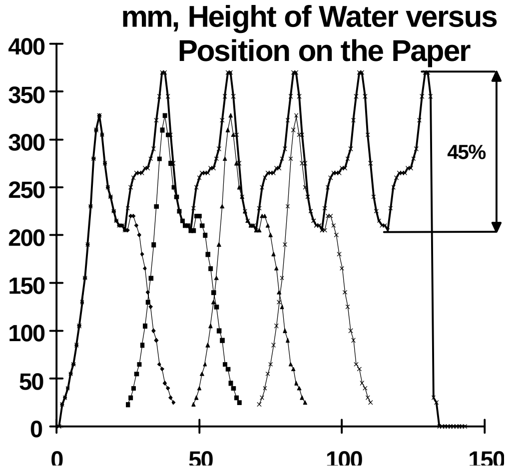

Fig. 5 Array distribution of 6 spray nozzle

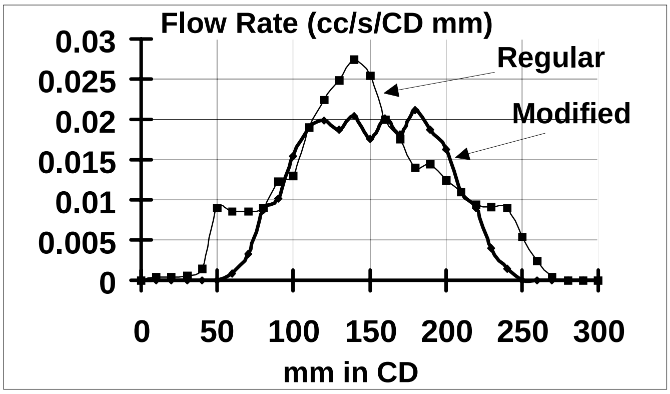

Fig. 6 Spray distribution of 2 nozzles with different orifice geometry

The peak to peak values of cumulative moisture profile vary by 45% which is too large to provide a consistent moisture profile across the paper sheet. Figure 6 shows a comparison of the spray pattern of a modified and regular market nozzles at 60 psi water pressure, 6” from sheet with zero degree offset angle. The geometry of the discharging orifice plays a very important role in controlling the spray distribution pattern. In this figure, it is shown that by modifying the orifice to change the circular shape of orifice to elliptical, the pattern has changed to a totally new characteristic performance. The width and angle of spray have changed which will alter the % of coupling.

Our currently used hydraulic nozzles can produce a fairly controllable spray distribution. The following figures show a reasonably flat distribution obtained from our current hydraulic nozzles. These nozzles provide a small peak to peak values and controllable moisture profiles.

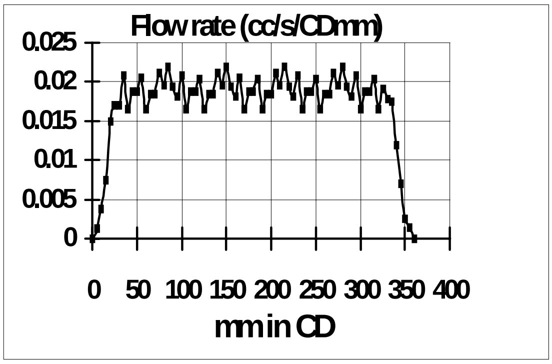

Fig. 7 Flow rate pattern of 5 flat fan nozzles at 80 psi , 3” from sheet and zero degree nozzle offset

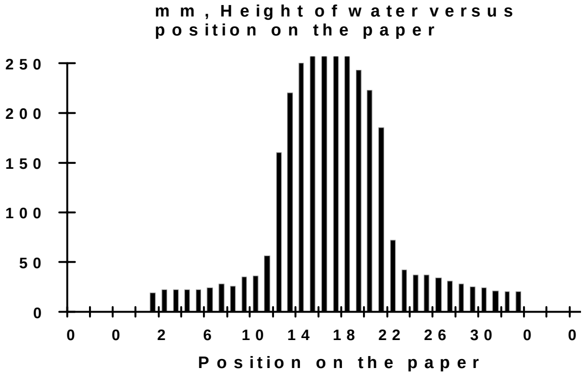

Fig. 8 single flat fan flow pattern generated from one of our current hydraulic nozzle at 3” from the sheet and 60 psi water pressure

There is very little overlap or pattern interference between adjacent nozzles in the paper cross-directional. Figure 9 demonstrates a hollow cone example of tested spray nozzles against the flat fan sprays. However, flat sprays are sensitive to blow out. This is when the air film following the sheet breaks the center of the fan pattern, causing it to curve in the direction of sheet travel. This can cause dry and wet streaks 2-3 cm wide. With the flat fan sprays, offsetting nozzles will help to reduce the % of coupling, improving the controllability of the moisture profile.

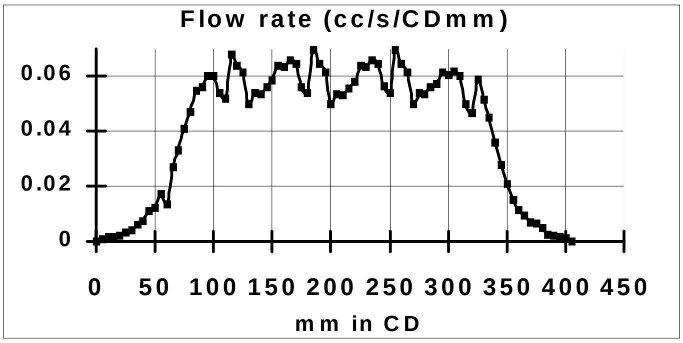

Fig. 9 Flow rate pattern of 4 tungsten hollow cone TN2 , 3” from sheet and zero degree nozzle offset nozzles at 60 psi , 3.1” from sheet, 3.02” zone spacing

4. Conclusions

1. Although the current hydraulic nozzles demonstrate a good degree of controllability of moisture profile, it is apparent that certain changes and modifications are needed for the improvement.
2. Extensive tests are conducted on hydraulic atomizing nozzles which help the understanding of the need for further nozzle development.
3. A great number of pictures are taken from various sprays, for sizing and momentum analysis of spray particles.

Acknowledgement

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