Some Factors Affecting Drainage and Sheet Formation

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Both in the case of open type head box where stock flows from the elevated screen into the transverse channel, or in the case of pressured head box, the paper machine stuff is with much turbulance and eddis which must be destroyed otherwise proper dispersion of the stock will not be achieved at the slice.

Perforated rolls called restifier rolls are installed before the slice door to minimise this turbulance and spreading the fibres uniformly. This roll destroys flock forming tendency of the fibres and the water mixture inside the head box. Rectifier rolls are installed inside the head box in different positions, combination of four to five rolls are seen in very high speed paper machines.

Stock enters the ascending chamber with relatively high velocity, then it passes through the dispersing slots which destroy the turbulance of the stock, but the stock needs further counter-turbulance effect for even dispersion, and the perforated roll does this job of destroying the residual kinetic energy and equalises the distribution of the fibres. The degree of this counter-turbulance depends upon the roll diameter, number of holes, hole size, and revolution of the roll per minute.

The last perforated roll should be placed at a sufficient distance from the slice lip so that the turbulance created by it should subside before the lip, or the flow just before the slice nozzle should be of isotropic character. Paper machine speed rising from 450/500 ft. per minute and further above needs to have rectifier roll or rolls. Paper machine making different grades of paper at different speed should have rectifier roll with differential speed regulator.

The head of the stock behind the slice, the direction of the jet, the angle at which the jets strike the wire, are of great importance, so far as sheet formation is concerned.

It is known that the required head at the slice increasses as the square of the velocity, the relation between head box stock behind the slice, and the mean spouting velocity is given by this equation $V=C_v\ 2\ gh$.

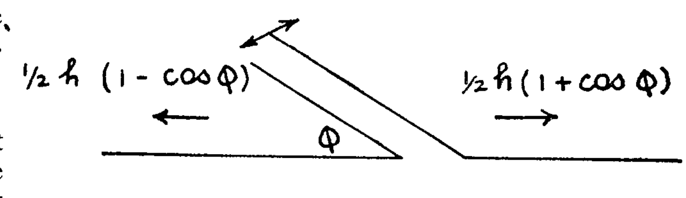
where V=Velocity of the jet (nearing the wire speed).
C_c =co-efficient of the velocity discharge through the nozzle and
H=head of the stock just behind the slice.

C_v is approximately 1.0 for all slices, but friction lost due to perforated roll reduce the C_v to 0.98.

Difficulties increase as the machine speed increases, above 1200 feet per minute hydraulic problems arise at the slice and in forming zone, which are difficult to solve. At velocity 1,600 ft. per minute, a head of 11.5 ft. and at velocity 2,600 ft. per minutea head of approximately 29.5 ft. are required. At such high speed, it is not possible to employ a static head, and so pressurised head box has been introduced.

When the jets strikes the wire obliquely with the velocity U at an angle O the theoretical picture, assuming that there is no friction between the stream and the plane, a fraction 1/2 (1-cos O) goes forward with velocity U and a friction 1/2 (1-cos O) goes backward. In fact, the jet strikes a wire that is moving forward with a velocity of same as "U" and the small parts of the stream that was shot backward, i.e the layer 1/2 h (1-cos O) will rapidly be stopped by turbulant friction and is carried forward into the main layer on the wire. The thickness of the fluid caused by back flow is in theory 1/2 h (1-cos O) where O = the angle at which the jet strikes.

h=slice opening.



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This amount of retarded fluid will rapidly decrease as h decrease or as the jet angle becomes flater. The phenomenon of "Back flow" has been found to be very important in the study of slice jet and obviously, sheet formation.

In case of good writing and printing papers, it should be seen that the stock jet is adjusted parallel to the wire. To achieve this, the slice nozzle is placed as near as possible to the wire and the two lips of the slice are made perfectly parallel to each other. In order to obtain a smooth and steady sheet formation, the jet should meet the wire just behind the top of the breast roll so that the drainage should begin when the fibres are uniformly dispersed across the wire.

In case of high speed machine more than 400 meter per minute the dewatering action of the breast roll and first few cable rolls are arrested by introducing the following devices :—

At high speed, the process of sheet formation and drainage occur in a very short period of time. In a new machine with a wire of 100 ft. long and a speed of 1650 per minute, the period of drainage on the wire is only about 1.5 seconds. This drainage time is increased by installing forming-board of slotted cover (surface of the cover—is hard bacalite or touffnol or special type of seasoned wood) of about 20 inches to 28 inches in length in machine direction, is installed. Forming-board supports the wire at the level of the crown of the breast roll and reduces drainage. Good support of the wire at this point is important in order to protect the wire against the relatively powerful impact of the stock, and in particular, to present a level wire surface to the flow. Forming-board can be adjusted both vertically and horizontally and is placed so close to the breast roll that the drainge effect of the roll is largely reduced and the air carried with the directed downwards. The drainage delaying function of the forming board allows sufficient time for spreading the stock on the wire and results in less variation of caliper over the width produced, the irregularities in the slice discharge are also regularised to a great extent. Drainage occurs through the length of the forming-board only by gravity. The outlet openings in the bottom of the forming-board box can be throttled, if required, to control and adjust the drainage effect of the forming board.

The first few table rolls (2-6) after the forming board, in case of a free stock are grooved to break up surface and thereby to reduce their suction effect. In case of very free stock (wedding and crepe tissue) these rolls are fitted with perforated Jackets, similar to dandy roll, by this arrangement the formation zone is extended and time for fibre orientation in the cross direction in also increased. In conventional wire frame, it has been seen that of the various factors to influence while water drainage through the wire, the major factor is the suction head created by the tube rolls. The suction head for any tube roll is proportional to the square of the wire speed and to the density of the white water at the given roll. The equation takes this form :—

$$H = 1/2\ d\ s^2 \quad \text{where}$$

H=suction head,
d=white water density at the point,
s=wire speed.

It has also been seen that larger tube rolls produce a greater effect than small ones in direct ratio of their diameters, that is a large tube roll has a greater effective drainage area than a small one, although the suction head is the same for both. It has also been reported that as the speed of the rotation of the tube roll is increased relative to the wire speed, the amount of water removed at the roll is increased. Increasing the speed by 56 per cent relative to the wire speed, increase drainage by 22%. With the conventional drive of the wire part from couch roll, the wire tension decreases towards the breast roll. The wire sags between the supporting tube rolls, specially at the first table rolls where the load is the highest and the wire tension lowest with a corresponding area of contact between wire and table roll surface. Thus at such places, the wire forms a catenary (chain curve). In case of large enveloping arcs and high wire speed, the water sheet is carried beyond the crown of the table roll and then drops back on the wire, the impact causes formation of a second wave. Apart from the point of waves in the sheet, this causes breaks at the dry end of paper machine.

Latest investigation on water removal at the suction box has proved that the drainage takes place immediately after the passing over the leading edges of the box and that the water is drawn back into the sheet by capillary forces, when the vacuum is interrupted. Owing to this reason, the modern practice is to use combination of narrow width suction boxes with increasing vacuum with close placing of the boxes. Experiments on suction box with variable suction are confirmed that reducing the suction area by 66% had almost no effffect on the moisture content of the sheet. On the first boxes only very low suction is needed to empty the large capillaries and to obtain the desired drainage. On the later boxes, high vacuum is applied to compress the sheet and to empty the fine capillaries.

From the experiment of Muller Ride on the suction boxes drainage, we can gather the following valuable information :—

He worked with three independent variables—suction time, vacuum, and stock freeness, these three regulate the two dependent variables viz., sheet dryness after the boxes and air sucked through the sheet over the boxes. It is a confirmed fact that an equal vacuum on all the suction boxes of a paper machine will not give a good dry sheet, but the arrangement where suction is adjusted gradually from the "Wet Boxes" to the dry boxes, is the desired adjustment. From the experiment of Muller Ride it was seen from a particular quality of known basis weight and stock freeness, an increase of vacuum from 6 to 24 inches mercury had no effect on sheet dryness below 13% dryness, it was also shown that in the above case an increase of suction time above 0.2 seconds had very little effect on dryness at any vacuum, it was also shown that freeness had little effect as long as the volume of air sucked through is constant. An easy draining sheet with high porocity may leave the suction boxes with higher moisture content than a less porous sheet.

Drainage at the suction box at different speed with different quality of paper is a complex subject and depends on the following factors viz., viscosity of water, surface tension, elasticity, compresisibility and porocity of the sheet.

Brauns and Oskarrsson calculated that the air passes or enters the web when the dry solid content of the sheet reaches 6.5 to 7.5%. Experiments carried out in the Paper Making Machinery Research Institute (Russia) showed that there is a period of only 0.035 seconds between the starting of drainage and the moments when air penetrates.

Paper web must get compressed before it reaches the dry suction boxes and this compression is done by using dandy roll between the wet and dry boxes.

Baldwin reported that after compressing the sheet with a dandy roll situated above the seventh suction box, the amount of water removed from the sheet was almost doubled, from 454 to 794 litres per minute, and the amount of air sucked through the sheet was reduced by almost three times (from 962 to 339 litres per minute), with a simultaneous reduction in vacuum from 190 mm. to 180 mm. Hg.

Dandy roll is widely used in manufacturing different grades of paper except the news, condenser, and grease proof varieties. Dandy roll not only compresses the fibre but also brings the fibre together, levels the upper side of the web, improves look-through, increases strength and reduces the tendency to tear.

There is minimum condition of web moisture content on which dandy roll will run and continuously compress the web, otherwise there will be dandy picking. Some authors advise that the dandy roll should be placed on a suction box (low vacuum) which will immediately take away the expressed water under the roll. In very light weight water-marked paper, dandy is found to be situated over low vacuum suction box. Dandy roll when driven by the wire will give certain amount of slippage. On a machine operating at a speed of 45 to 50 m/m. the dandy roll is 1.5 to 3 m/m. slower than the wire, at a machine speed of 135 to 185 meter per minute the lag increases to 5-8 mm. per minute. The lag causes breaks and bad sheet formation. On a higher speed the dandy roll is to be driven by synchronised driving device.

Rubber covered rider roll over suction couch helps to compress the web further, giving better sheet.

Sheet formation is a very complicated process and is mainly a filtration problem involving flow through a highly porous compressible media of increasing thickness and weight which is being deposited from a dilute fibre water suspension.

An increase in the quality and economics of the process is largely dependant on good sheet formation and drainage at the forming zone of the wire part which will be able to give good interlocked sheet at low head box schopper (Power for beating and refining saved), appropriate grouping of tube rolls and properly designed forming boards and suction boxes.

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