Wet end operation of a paper machine

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SUMMARY

This paper deals mainly with the process of papermaking in the wet-end part. The course of the papermaking process is analysed to illustrate how each functional operation performed on the machine influences the final product. The analysis starts with the role played by the headbox slice and its approaches, approach flow, holeyroll etc. The effect of slice on fiber orientation, flocculation and jet delivery is considered. Formation on fourdrinier wire part, taking into account the effect of increased wire length, forming board, table rolls, foils, deflector and wet suction box on drainage, is discussed. Being a part of the wet end operation dandy roll, suction boxes and couch working are also considered. The changes made at the wet end at W.C.P.M. on the fourdrinier machines and improvement obtained by these modifications have also been discussed.

The standard laboratory hand sheet usually represents the most uniform orientation of the fibers possible from a given sample of pulp. Such a sheet is often regarded as a standard against which machine made paper may be compared. The laboratory sheet is made with highly dilute stock (0.0125% cy.) thorough mixing of the fibers and slow vertical drainage with very little relative motion in the plane of the forming wire. The conditions on the average fourdriner machine are very different in every respect. Variation from laboratory to production machine therefore requires an understanding of the factors operating during these dissimilar conditions of sheet formation.

The factors which affect the formation of paper on fourdrinier machine wet end parts are discussed sequentially in the following sections.

APPROACH FLOW

The function of the approach flow system is to deliver the stock to the headbox uniformly and evenly from one end to other end. This is very difficult to achieve in the absence of good approach flow design. At W.C.P.M. both fourdrinier machines were equipped with equal split flow design in which the stock enters the headbox from both sides. The shortcoming of this design was heavy turbulance at the centre of the head box where both flows meet. This causes vortices in head box and forms channels on wire resulting in weight variation across the machine. In 1971 PM I approach flow was replaced by better design approach system i.e. tapered manifold inlet and controlled recirculation from the exit side. Due to tapered design of pipe, pressure from one end of pipe to other end remain more or less constant and flow enters the head box at every 100 mm distance through a manifold (33 branches in 3.5 meter width head box) which results in uniform flow to head box.

HEAD BOX :

If the approach flow system is efficiently designed, the flow velocity can be kept uniform over the whole width of the machine. In the absence of cross currents and only a relatively small degree of turbulence sufficient to keep the individual fibers in random suspension without flocculation, the head box would serve only to provide sufficient head at the slice. It is the deficiency in the approach system which necessitates a good head box design with devices to help even out unwanted disturbances and poor uniformity of the incoming stock.

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At W.C.P.M, open type head box on PM I was replaced with a modern pressurized head box with auto level controller, and pressure controller. This head box is able to take care of small variation in level due to pumping and other electrical, mechanical problems. Level chart on head box panel shows practically very steady straight line. W.C.P.M. has observed improvement in basis weight profile after installation of this head box. With automatic control system in head box, operation has become simple compared to manual system.

THE SLICE

The head box slice serves the following functions on the fourdrinier paper machine :

1. A metering gate to control the mass distribution across the machine.
2. A constricting orifice to the flow in the head box to raise the velocity of the diverging jet close to that of the forming wire.
3. A compensating control for distribution deficiencies in the head box proper.
4. A control to provide temporary relief for such operating problems as incorrect roll crowns, plugged felts, dryer ventilation deficiencies, etc.
5. To control the angle and line of impact of the jet on the wire.
6. To control orientation of fibers in the jet.

Slice design ranges the whole gamut from vertical slices to near parallel nozzles and are usually closely associated with a flow conditioning device just ahead of them in the head box.

This device might be generally one or more holey rolls or a nest of flow guiding vanes. The function of these devices are to reduce cross flows and to add a sufficient degree of agitation to break up the fiber flocs prior to discharge through the slice.

Paper makers control the average cross directional basis weight profile by varying the slice opening across the machine. The effect of an adjustment to the slice at one point usually produces a change over a wider area of the machine.

Sometimes the slice must be used to compensate for non-uniform velocities approaching the slice. For example, on a head box with several high velocity inlets, the individual streams may not be completely diffused on reaching the slice and heavy streaks result in line with each inlet. The slice is usually adjusted in an attempt to spread these flows more evenly but never with complete success. Whenever an excess flow approaches the slice, there is a cross-flow set up towards those part deficient in flow. The combination of the flow across the slice with the accelerating flow in to the slice produces vortices that are drawn out through the slice. On the wire these vortices become unstable and produce weight variations.

APPROACH SYSTEM, HEAD BOX AND SLICE AT W.C.P.M.

On PM I at W.C.P.M. most of the problems from approach, head box and slice were taken care of by the new closed type head box which works on the principle of a constant stock level over the entire machine speed range. The tapered manifold with its flexible, equally spaced distribution pipes, provides an optimum flow distribution of the stock across the width of the machine. The special construction of the distribution system assures the wide throughput rates. After passing the distribution pipes with increased velocity, the uniform, individual flows are united and intensively mixed in the mixing chamber, and the high velocity of the stock decelerates. Thus the throttled suspension leaves the mixing chamber with constant flow rate and passes through the head box at constant level to the slice in a straight forward way. The complete prevention of cross flows guarantees high throughput rates without flow disturbance. The evener rolls inside ensure an equal micro-turbulance. Uniform basis weight is mainly achieved by the careful finish and the accurate operational adjustment of the slice.

The basis weight across the machine direction can be corrected by means of the adjusting spindles. These spindles are connected to the top slice lip and distance from one spindle to the next is 150 mm. There is a fine control of the slice and it can be corrected to 0.1 mm opening.

Due to these modifications W.C.P.M. is able to control its basis weight profile on PM I within $\pm$ 2%.

SHEET FORMATION AND DRAINAGE ON THE FOURDRINIER

The angle at which the stock hits the wire and the place of impingment are of paramount importance to sheet formation. Speed difference between stock flow and wire also influences the sheet formation. If velocity profile of out flowing stock in cross direction is even and speeds of wire and stock

are equal, the sheet formed in this manner will be ideal and will have properties equal in machine and cross direction similar to the laboratory made sheets. In practice this is not possible.

More fibers are printed in machine direction and therefore, machine made paper has more tensile strength in the machine direction as compared to the cross direction

The effect of the difference in speed of stock and wire on fiber orientation and properties associated with orientation is reasonably well established. Breaking length at jet/wire speed ratio of 1:0 is lowest in machine direction and highest in cross direction.

On most paper machines a compromise is necessary on the one hand to avoid excessively rapid drainage in the first few feet of wire length, which is liable to disrupt the whole structure of the sheet, and on the other to avoid delaying drainage to such an extent that the sheet leaves the couch very wet and the head box consistency has to be raised to off set this. On higher speed machines early faster drainage causes wire mark in the sheet. Controlled drainage within a few feet from slice is very effective in forming good sheet.

The zones of particular interest are the landing area of the jet on the wire, the areas over and immediately following each table roll and the areas over drainage foils. The feature common to all these is that in them the stock changes its direction of travel. The jet makes a slight angle of impingment on the wire. At table roll, the stock changes direction two or three times and, at the foils, twice. The cause for the deflection at the roll and foil is the hydrodynamic suction created in the outgoing divergent nip. Important point to note is the peak suction of the foil is very much less compared to a table roll and duration of suction is more whereas roll created suction is relatively short. Advantage of a foil is the reduction in stock jump and disturbance to the underside of the sheet at faster speeds; over a foil any depression in the stock surface gradually grows in the same way that occurs over the suction area of a table roll, but impulse to the wire at the point where suction is broken is much less. For these reasons foils are in use on many high speed machines in the early part of the drainage area where it is desirable to reduce stock jump.

At W.C.P.M. fourdrinier machines drainage is controlled in the earlier part of the wire by providing a 46.5 cm wide forming board and next to it a grooved table roll. Further down, five double blade deflectors are provided inbetween the table rolls. Wire length was increased from 24 meters to 30.15 meters. This arrangement has improved the sheet formation within acceptable limits upto 250 gsm paper, which was not possible earlier with 120 gsm paper and above. Sheet formation and properties have been found to be better at jet/wire speed ratio between 1.1 to 1.2.

SHAKE

Shake is more effective in slow speed machines as compared to higher speed, and it results in the following benefits.

1) Evenness of fiber orientation and also, to some extent, the ratio of strength tests in the machine and cross directions improves with application of shake.
2) Formation improves with shake and it is more effective in wet stocks.
3) Controls the drainage.
4) Higher amplitude of shake increases average strength properties whereas higher frequency of shake has more effect on formation.

At W.C.P.M. improved shake design, which gives parallel shake to 4.8 meter length of wire part from breast roll at three equally spaced points, and angular shake to 2.7 meter wire part further down, has contributed significantly in improving the sheet formation.

SUCTION BOXES :

Suction boxes are installed at a point on the wire where table rolls can no longer efficiently remove water. These boxes remove more water than table rolls above a certain sheet dryness. It is advised to install suction boxes side by side with no air space between them to obtain maximum efficiency. The number of boxes may vary from five to ten as per the machine speed. Where a dandy roll is used two to four boxes are installed ahead of it. These boxes must not increase sheet dryness above the point where fibre picking may start on the dandy roll.

Proper levelling and positioning of the boxes is very important as any difference in level will increase wire wear and vacuum will fluctuate erratically at one or serveral boxes. If the boxes are not absolutely perpendicular to the machine direction, they will tend to carry the wire towards one side.

The boxes should carry a gradually increasing vacuum from the first wet box to the last dry box since these give higher sheet dryness than an equal vacuum on all boxes although the sum of the vacuum readings may be the same in the two cases.

At W.C.P.M. PM I there are ten suction boxes in use One suction box is used as wet suction box between the table rolls and four boxes are before dandy roll. Rest of the five boxes are after the dandy. These boxes are connected with broughton vacuum system which is one of the best known systems for efficient dewatering through the boxes. Each individual box is connected with suction leg in increasing order of vacuum which provides higher vacuum in each succeeding box which is a important factor in dewatering the sheet as its dryness increases. This system has provided W.C.P.M. with a good tool for controlling water line on wire.

With addition of one wet suction box, between the table rolls, better control on drainage has been achieved. In heavier substance paper head box consistency could be reduced resulting in better basis weight profile across the width and better sheet formation.

DANDY ROLL

The dandy roll functions are two fold :

For plain wove papers it improves fiber distribution by helping to deflocculate and give more uniform fiber distribution through the web It also improves the top surface of the web by closing it and improving the strength and porosity of the paper. The second main function of dandy roll is to produce water marked grades with special finishes.

Correct dandy roll performance can be a critical element in producing paper quality, and incorrect operation can be expensive in terms of downtime and paper waste.

Dandy roll is manufactured wider than the paper machine width to prevent wear of the paper machine wire and stock build-up in the non-drainage area of the roll. The diameter is selected according to maximum speed where the objective of maximum contact time, quality of water mark, minimum water throw and sheet disturbance at the out going nip must be balanced against additional costs of longer rolls.

At W.C P.M, PM I earlier dandy roll was of 500mm dia. This has now been increased to 600mm. The change to higher diameter has permitted W.C.P.M. to run dandy with wet stock and upto 250 m/min speed without water spots or dandy marks in sheet.

At higher machine speeds dandy roll must be equipped with continuous self cleaning shower and vacuum box to avoid fast plugging of the dandy.

THE COUCH

The usual couch today is the suction couch with or without a pressure roll. The pressure roll is generally called lump breaker and is covered with soft rubber. The purpose of this roll is to compact the sheet and increase sheet dryness. The lump breaker contact width on couch should not be more than the suction box width in the couch. In that case lump breaker will pick the sheet from the area not covered by suction box. This was the problem earlier in W C.P.M. and it was solved by giving under cut to the lump breaker on both sides which were not covered by the couch suction box.

CONCLUSION

Proper design and operation of the wet end of a paper machine is most important for it is here that the paper web is first formed. As discussed in this article, each component of the wet end has a distinct role to play in making a good sheet of paper. The various modifications carried out at W.C.P M. on the fourdrinier machines enables the mill to make papers of a very wide grammage—48 to 250 gsm. The wet end is capable of handling stock upto a head box slowness of 60°SR and has modern features to run long or short fibre stock. An advanced approach flow system, head box and slice reduces the chances of basis weight variations.

Continuing with the above innovations, W.C.P.M. has recently introduced synthetic forming fabric supplied by SWIL on PM I. So far it has run for about 2 weeks quite successfully while introducing the forming fabric no other changes were necessary on the wet end. The effect of the forming fabric on machine performance, paper properties, etc. is being studied.

Thus it may be said that continuous emphasis on development of the wet end of fourdrinier machines at W.C.P.M. has paid rich dividends in terms of better machine runability and paper quality.

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APPENDIX—I

Details of original and modified wet end part :
PM I of W.C.P. Mills, supplied by Escher Wyss, Germany.

	Particulars	Original	Modification	Advantage
1.	Cleaning system	Strainers	Three stage vorjects cleaning (12 + 4 + 1) and Bird screens before head box.	Cleaner paper.
2	Approa\h flow	Equal split flow	Tapered side inlet manifold	Uniform basis weight across the width.
3.	Head box	Open type	Closed type pressurised with auto level & pressure control	Better control & operation at higher speed.
4.	Forming table	Only table rolls (20 Nos)	Forming board 465 mm width one groove table roll, 19 table rolls with 5 deflectors & one wet suction box	Controlled drainage – better formation.
5.	Wire length	24 meters	30.15 meters	Improved formation.
6.	Shake	4.9 meters long table under shake	7 5 meters table under shake (4.8 meters parallel & 2 7 meters angular shake)	Better fiber orientation.
7.	Wire table length	10 meters	13.5 meters	Better formation at increased speed.
8	Suction boxes	8 Nos.	10 Nos including wet suction box	Better drainage.
9.	Suction box vacuum system	Ordinary through vacuum pump.	Broughton vacuum system. Gradual increase of vacuum in succeeding boxes through separaters	Increased sheet dryness
10.	Wet suction box	No provision	One wet suction box at about 8 meters away from head box	Reduced head box consistency.