Effect of Headbox Operational Variables on Paper Formation

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The effect of slice opening and perforated roll speed on paper formation at various machine speeds were studied on pilot paper machine. The plot of formation value vs. slice opening at a given machine speed is parabolic and for best formation the optimum slice opening corresponds to the apex of the parabola. For same formation when other variables are kept constant and optimized, the graph of machine speed vs. slice opening is a straight line i.e. the formation at any speed is a function of the jet to wire speed ratio and the absolute value does not have to deteriorate with increasing machine speed. The perforated roll speed also affects the formation and any increase or decrease in its speed, above all the necessary value to maintain cleanliness and deflocculation of stock causes a deterioration in formation.

INTRODUCTION

In general there are three distinct areas which effect formation. The first are those external to the paper machine system such as stock quality and uniformity. In second category there are groups of variables related to the Fourdrinier, which includes such as table roll balance, wire tension, Fordrinier levelness and regidity, table rolls and deflector configuration. The third and most important category contains the group of variables which can be controlled on a day to day basis and on whose optimization a large percentage of paper quality depends.

On the head box variables a great deal has been published. The effect of various adjustments on the slice of a paper machine concerning such items as jet speed to wire speed ratio, jet angle and perforated roll speed are covered in literature[1-6]. Most of this work has been directed particularly at machines of rather modern design and therefore relatively high speed. In India we are having a large number of smaller, older and slower paper machines and it was felt that some of these principles of operation, which can be a routine control for paper formation could be applied to these machines.

Experimental Procedure

Pulp was prepared from pulp sheets to yield a furnish of 60% softwood sulfite and 40% hardwood kraft. A basis of 150 pounds of bone dry stock was selected. At a moisture content of 10% this amounted to 165 pounds of pulp sheets. Five per cent china clay filler was added on a bone dry basis The pulp was beaten in the hydrapulper in six batches each batch being successively pumped to the storage chest. From storage, stock was pumped through the Jordan refiner to the machine chest where it was stored until use. Flow in the Jordan was 20 gal/ min. The stock was stored in the machine chest at a consistency of 1.9% and a corrected freeness of 380, at 22 °C Stock already in the machine chest at 1.9% consistency was diluted to 0.66% in the machine chest and pumped continuously to the surge bin and into the headbox. Four formation readings were taken at four different slice openings for each machine speed of 25, 50 and 60 ft/min. At each machine speed and a slice opening of 19/64" the perforate roll speed was varied to three different settings and formation readings were recorded.

The Paper Machine

The paper machine under study in this case had an open slice box 12.75 inches wide and 20 inches long containing two baffel plates and one perforated roll. The diameter of the perforated roll was 3 inches. The distance between the breast roll and couch roll was 7 feet 11 inches and the wire width was 17 inches, twill weave 56–65 mesh. The Fourdrinier table had 14 deflectors each 1.75 inches wide and 15/16 of an inch thick, The suction part of the wet end consisted of three suction boxes with a total suction area of 25.8 square inches. There was no suction on the couch roll nor on the plain or rever-

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se presses. Thirteen dryers were used, each with a diameter of 15.75 inches.

Operating Conditions

The machine was operated with no white water circulation, nor was any shake applied to the Fourdrinier wire. Suction box vacuum was 3 inches Hg and the pressure on each of the two presses was 20 psi. There was no heating in the first and second bottom dryers. Formation readings were taken in milliamps on a two spot formation tester.

Formation Tester and Recorder

Formation measurement has not been widely practised even though a formation tester was developed by Davis, Rochr and Malmström[7] as early as 1935 followed by a commercial unit in 1936.

Other instruments have been developed since then most of which have been on analysis type for Laboratory investigation incapable of giving a measure of paper structure adequate to evaluate the effect of variables of the paper making process or specific aspects of structure uniformity pertinent to printability. Burkhand, Wrist and Mance[8] developed on machine formation tester called ONS/Mead formation tester. Eastwood[9] of Kimberly Clark Corp. developed first time two spots light formation tester.

In this study Kimberly–Clárk two spot continuous formation tester was used. It has two photocells and two apertures to obtain formation. independent of change or speed between 50 to 3500 fpm. The variation in the average value of a beam of transmitted light is used to measure the small basis weight variations known as formation. The configuration of the instrument is shown in fig1, and the arrangement by block diagram is shown in fig 2. The details of the development and functioning of this instrument are well described in literature[9]. In this paper formation will mean the output reading of this instrument in milliamps.

Statistical Procedure

To determine the effect of slice opening on formation, formation readings in milliamps were plotted against corresponding values of slice opening. This was done for each machine speed producing a family of three curves. This same method was used to determine the effect of perforated roll speed on formation. Formation readings were plotted against roll speeds and again three curves were obtained, one for each machine speed used.

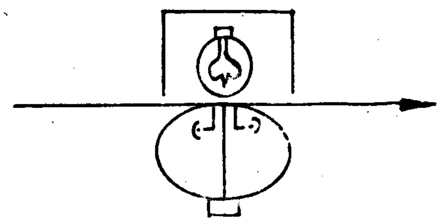

Fig. 1. Idealized Digram Kimberly Clark Two Spot Formetion Tester

Table I

Formation Reading at Different Machine Speed at Different slice opening.

S. No.	Machine speed (ft/min)	Slice opening (inches)	Formation (milliamps)
1	25	12/64	100
		16/64	97
		19/64	94
		21/64	95
2	50	12/64	100
		16/64	92
		19/64	90
		21/64	95
3	60	12/64	100
		16/64	90
		19/64	88
		21/64	95

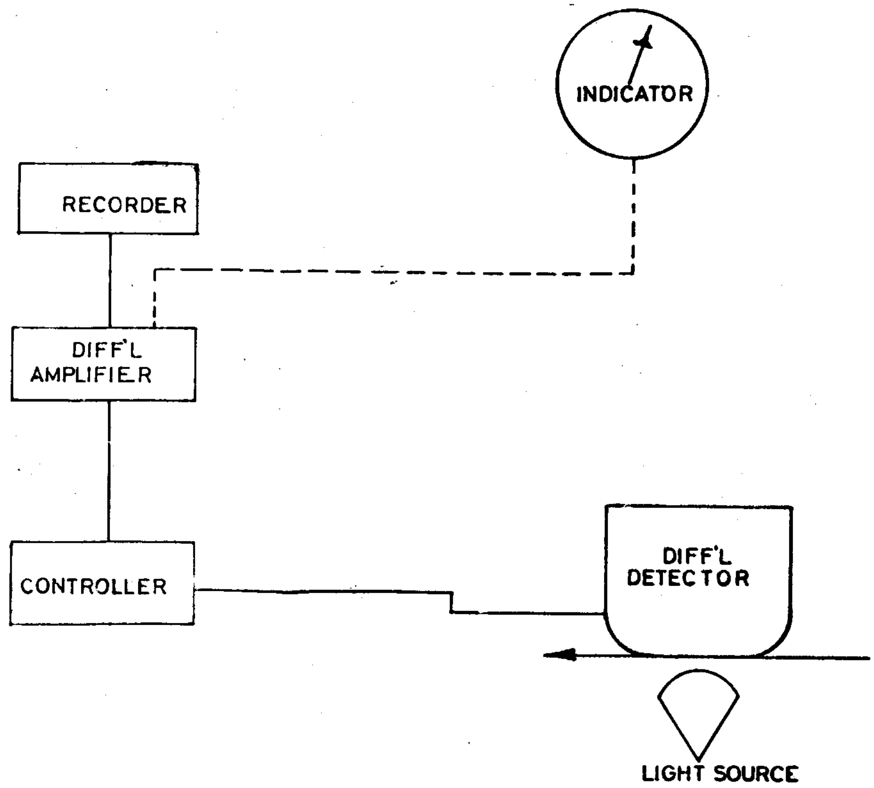

Fig. 2. Block Diagram

Table II

Formation Reading at different Machine speed for different perforated roll speed.

S. No.	Machine speed (ft/min)	Perforated roll speed (rpm)	Formation Milliamps
1	25	40	99
		60	98
		85	95
2	50	40	98
		60	96
		85	90
3	60	40	95
		60	90
		85	91

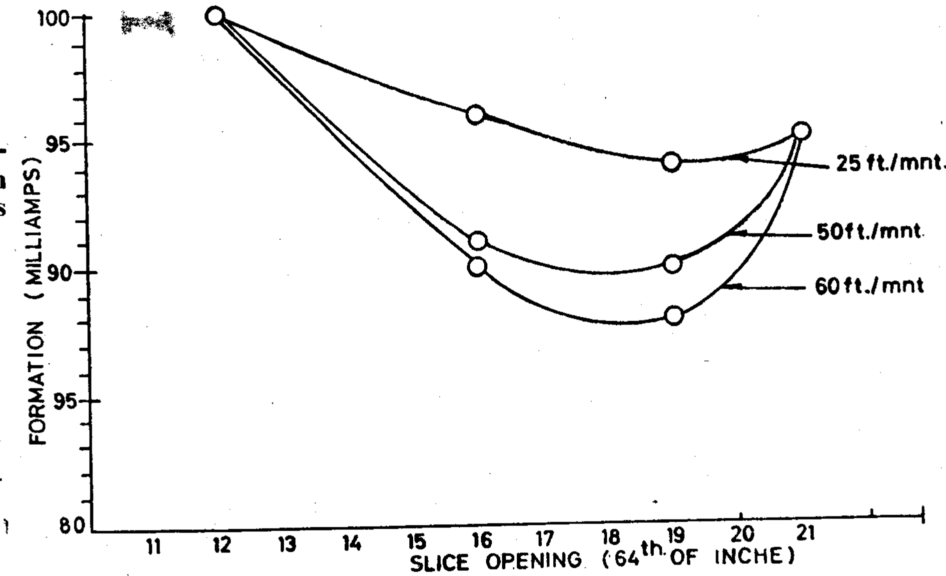

Fig. 3. Formation Vs. Slice Opening

Discussion

The most important and controllable of the head box variables is the relationship between the jet speed as delivered on the wire and wire speed. This ratio is also called efflux ratio. Jet speed is given by the formula

$$V = C\sqrt{2gh}$$

where V= Jet speed

C= cofficient of velocity discharge.

g= gravity constant

h= Static head of stock behind the slice.

So jet speed is directly proportional to head and which is inversely proportional to slice opening for constant speed and basis weight. A graph between formation value and slice opening at different speeds is drawn in Figure 3.

The shape of the curves for all the three different speeds is parabola with a vertex at particular slice opening for each speed. The optimization curve shown in figure 3. can be described by the parabolic equation:

$$y^2 = 4ax$$

where y = jet to wire speed ratio.

x = formation index.

a = constant.

If in the above equation 'y' is replaced by jet to wire speed ratio and this is equated to jet-speed equation, it is possible to obtain a direct relationship between wire speed and head as described below :

$$\frac{V^2}{S} = 4ax.$$

whers S = wire speed.

The jet speed is already described by the epuation.

$$V = C\sqrt{2gh}$$

$$= \frac{(C\sqrt{2gh})^2}{S} = 4ax$$

$$X = \frac{C^2.g.h.}{2aS^2}$$

$$X = K.\frac{h}{aS^2}$$

when for particular slice and same geographical conditions 'C' and 'g' are constant and substituted by K while 'a' is constant, characteristic of the head box which described the sensitivity of unit charge in the jet to wire speed ratio on formation. So for keeping the same formation value the apex of the optimization curve 'a' and 'x' will become constant and substituting these constants by K^1 head is directly proportional to the square of the velocity.

$$S^2 = K.^1 \frac{h}{ax}$$

$$S^2 = K^1h$$

$$S^2 \propto h$$

Thus for the same formation value we should get a straight line relationship between machine speed and head or between the machine speed and the slice opening, when all the other formation affecting variables are kept constant.

In Fig 4. machine speed is plotted against the slice opening at best

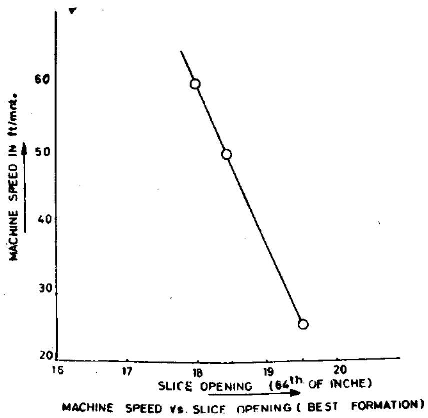

Fig. 4

formation value obtaining by drawing tangent to the curve in Figure 3. It is a function of straight line, as proved by the above equation. So the ratio of machine speed to slice opening or jet speed is constant for better formation i. e. if wire speed is changed for better formation, slice opening is the changes. Such simple ratio is used in computer for keeing formation and reducing production loss. In figuse 3, the best formation cruve was obtained for higher machine speed. This is against the long held theory that formation must deteriorate as machine speed increases. When other variables are kept constant and optimised, the formation at any speed is a function of the jet to wire speed ratio and the absolute value does not have to deteriorate with increasing machine speed. The pretreated roll helps in reducing flocculation and rectifying the flow defects, which enter in the head box from distribution system. Their position within the head box and their setting in relationship to each other with the walls of head box is of critical importance for adequate flow rectification. The efficiency of flow rectification can also be influenced by the hole pattern of the perforated rolls and their speed of rotation.

It was tried to see the effect of perforated roll speed of rotation on formation. It was observed that in slow speed machine even the maximum speed of rotation is insufficient to get the optimum condition for better formation. In slow speed machine stock distributor plays an important role for uniform dispersion.

For this head box system at machine speed of 60 ft/min, the best paper formation is obtained at perforated roll speed of 72 rpm. from Fig. 5. Thus at higher machine speed it appears that any increase or decrease in perforated roll speed, above all the necessary value to maintain cleanliness and deflocculation of stock causes a deterioration in formation.

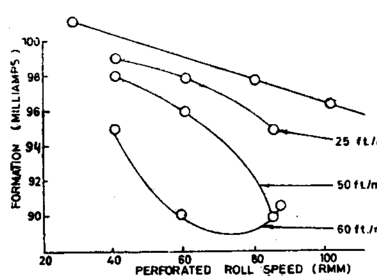

Fig 5. Formation Vs. Perforated Roll Speed

Conclusions:

Paper formation is the end result of the complex interactions of relatively simple variables, some of which are controllable on any machine. The optimization of formation is limited by machine design and the stock quality considerations which are very often beyond the control of the paper maker to change. At some time, however, there are enough controllable variables that for a given machine the optimum paper formation should be achievable and repeatable if these variables are closely watched.

Even at higher machine speed the formation can be maintained by adjusting the operational head box variables.

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