Modeling and Simulation of Approach Flow for GSM Control

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Often short term grammage fluctuations take place on paper machine with a very small time lag. Due to the same, both MD and CD variations occur and these cannot be controlled with the conventional consistency and stock flow control techniques. Modeling and simulation has been tried to understand the reasons behind these variations and suitable corrective actions have been suggested in this paper.

INTRODUCTION

With increasing concentration towards quality control, process plant operations are becoming more and more important. Extensive use of automation has been able to solve some of the problems, but many other problems appear and make the target of total quality control very difficult. Basis weight control has been an issue of interest for paper makers since long, but some variations mainly of chaotic nature remain present.

With automation, severe grammage variations have been avoided and it has been possible to run the paper machines at increased speed and production rates. Still, papermakers feel that there is something that affects GSM (both MD and CD) and some variations remain present always. The objective of this work is to analyze this problem with the help of modeling and simulation, and to ensure control within a smaller range.

Methodology

In the first phase, a conventional approach flowsheet was taken, and the performance data was generated with the help of a computer. This flowsheet considered a single dilution system; a three stage cascaded centricleaner, a two stage screening system with one hole screen and another vibrating screen, a tapered manifold and open headbox. The backwater from the wire part was being taken to backwater silo, which is used for dilution in fan pump. This block diagram of this has been given in Fig.1.

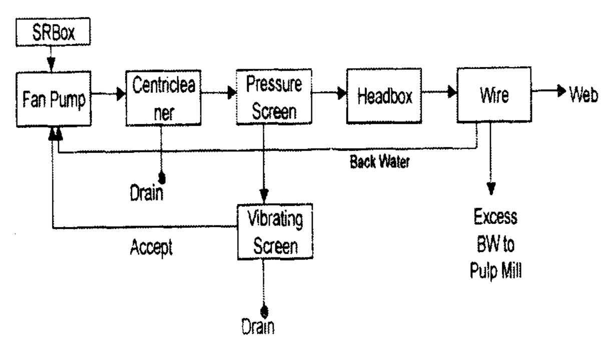

Fig. 1 : Block Diagram of Approach Flow System

First of all material balance calculations were made.. The output from these equations was used as initial operating values for the machine. Later, the effect of change in different parameters was considered for change in stock flow through basis weight valve, stock consistency in the machine chest, first pass retention etc. For a detailed analysis, more information was needed regarding the mechanical details regarding equipments, piping etc. For this data were collected from the mills.

One of the problems faced in such cases is that the behaviour of the process may differ with change in parameters. There are some examples to this- in transition regime of pulp flow in pipelines, friction loss drops with increase in pulp velocity .This affects the process in its own way. One increases valve opening to reduce the flow rate, but it increases. We increase vacuum at wire part hoping to get higher dryness after couch roll, and hence after press roll, but an abnormal high vacuum at the wire.part reduces the web temperature affecting press part efficiency adversely. As a result, we may get no benefit or even a reduced dryness after the press part. It has been observed that reduction or even total stoppage of vacuum in suction couch produced no adverse effect on web dryness after press[1].

Since such complex behaviors cannot be considered in detail, this was taken up in the second phase. With this a real time model was developed and experiments were made with the help of it to explore the effects of different process and operating conditions towards a better GSM control.

Basic Material Balance Equations:

Under stabilized conditions, the complete material balance can be carried out using the following basic equations-

$$C=100 * S/F$$

$$\Sigma S_{in}= \Sigma S_{out}$$

$$\Sigma F_{in}= \Sigma F_{out}$$

Where, C is the consistency, S is the solids flow rate and F is total flow. Subscripts in and out represent inlet and outlet conditions at any considered section. For every stream, and process equipment, such equations may be written, and solved to obtain the value for unknown parameters.

Simulation of Process Operations

Now, depending on the equipment details, piping size and layout etc., the change in process conditions can be computed. As different equipments have different behaviour, we write equations for these -

PIPE

In the pipe no action takes place on the pulp, and there is only a time lag. This time lag is equivalent to the ratio of pipe volume to volumetric flow rate through the pipe. Mathematically -

$$C_{(out,\,t)} = C_{(in,\,t-V/F)}$$

$$F_{(out,\,t)} = F_{(in,\,t)}$$

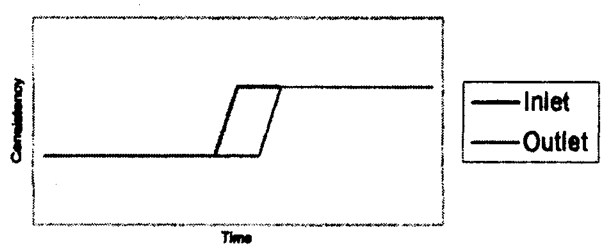

Fig. 2 : Outlet Consistency as a Function of Inlet Consistency and Time in a Pipe

Centricleaner

Centricleaner is another interesting area. While centricleaner accept consistency and flow change with change in feed consistency and flow, the straight through header also affects the time response behaviour of centricleaner system. We may understand the behaviour by this- a part of the stock entering centricleaner header goes to first centricleaner bottle, and comes out after a short while. Another part of the remaining stock enters the next centricleaner bottle and comes out after some more time, and so and so forth. Thus, any abrupt change in centricleaner inlet consistency , results in slow change in accepts consistency . Flow, of course, gets stabilized soon.

For inlet consistency of $C_{i,I}$ initially, and $C_{i,\infty}$ finally after step input change, and out let consistency initially at $C_{out,0}$ and after stabilization $C_{out,\infty}$, outlet consistency at any given time t can be expressed as-

$$C_{out,t} = [(n-m)*C_{out,0} + m*C_{out,\infty}]/n$$

Where, integer m is such that -

$$\Sigma(t_l .. t_m) < t \leq \Sigma(tl .. t_{m+l})$$

Where,

$$t_i = ((l-n)*V_{i,n}/F) + (((l-n)*V_{out,n}*C_{i,\infty})/(C_{i,0}*F))$$

Where,

F = Inlet flow rate to centricleaner

n = Number of centricleaner bottles in operation

$V_{i,n}$ = Volume of centricleaner inlet header just prior to nth bottle

$V_{out,n}$ = Volume of centricleaner accept header just after nth header

The output from above equation has been given in fig. 3.

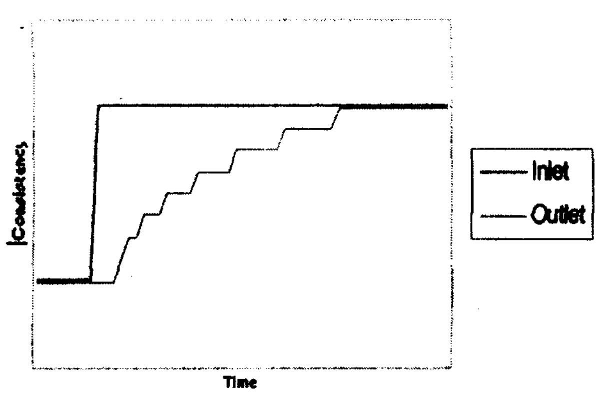

Fig. 3 : Centricleaner Accept Consistency as a Function of Time

Pressure Screen:

Pressure screen may be considered as a mixer. Since a fraction of the fibre is lost from screen through reject, which is normally taken out from the loop, we may understand that first the inflow is mixed with the contents in the screening chamber. Than the reject is removed and then a part of the remaining material leaves the screen to head box.

For out let consistency initially at $C_{out,0}$ and after stabilization $C_{out,\infty}$, outlet consistency at any given time t can be expressed as-

$$C_{out,t} = C_{out,0} + e^{-a/t}(C_{out,\infty} - C_{out,0})$$

Where, constant a is such that-

a= Screen Volume/ Volumetric Flow Rate

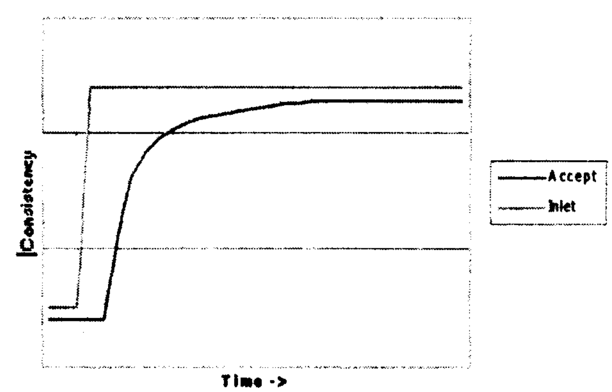

Fig. 4 : Pressure Screen Accept Consistency as a Function of Time

The simulated output from the above equation has been given in Fig. 4.

Manifold

The manifold also behaves in the same fashion. In case of a tapered manifold, if there is a change in consistency at manifold inlet, apart of this stock enters the first nozzle. Another part of the remaining stock enters the second nozzle and so and so forth. Equations similar to those of centricleaner can be written for manifold also, the only difference is that the manifold has only inlet header, and output is different at different positions, while in centricleaner there are separate headers at inlet and outlet, and the outlet is available at a single position.

The final result is that whenever there is a change in inlet consistecy at the manifold header, CD profile unstability[2] appears for some period of time. This is because of the fact that the entering stock reaches different CD positions in a headbox at different times. As indicated above, if there is a continuously changing position of manifold entering consistency , the CD profile will be continuously disturbed. This can be understood from Fig.5.

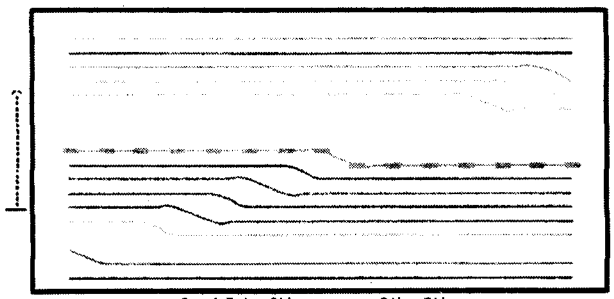

Fig. 5 : CD profile disturbance due to Sudden Change in Manifold Inlet Consistency

This affects in altered GSM at the position of this nozzle. After a short while, more and more nozzles start getting the pulp at newer consistency. Thus there appears a CD GSM variation. In most of the cases, an abrupt change in basis weight valve opening is so slowly stabilized that it may need even a couple of minutes for the approach flow system to get stabilized.

Wire

It seems surprising, but the wire also plays its role in GSM related activities. In normal operations, head and slice openings are made constant, and to change GSM slightly, only headbox consistency is changed. We know that increased headbox consistency results in increased retention and reduced backwater consistency , and vice versa. Following types of equation can be derived for a given system-

$$BW = A-B*HB$$

$$BW = A/HB$$

$$BW = A* HB^{-B}$$

$$BW = A * Exp (-B*HB)$$

$$BW = A * In(HB) + B$$

$$BW = A*HB^2+ B*HB + C$$

Where, A,B and C are constants, BW is backwater consistency and HB is headbox consistency .Depending on process data, the most suited equation can be used for further analysis.

As indicated above, any change to alter GSM slightly, results in relative change in headbox consistency , and thus an opposite change takes place in backwater consistency. Later on, when this backwater reaches fan pump through backwater silo, the situation gets reversed in opposite direction. In some of the cases, particularly, where the retention is very low and head box is operated at very low consistencies, the affect of this phenomenon is significant. For a quantative view, let us have a look at some typical figures -

Head Box Consistency	Back Water Consistency
0.85	0.15
0.75	0.20
0.65	0.28

Using regression, we may compute the simulated effect of head box consistency change to change in backwater consistency and hence again the headbox consistency. Let us assume 48 GSM paper is being made at any of above headbox consistency. Machine Chest consistency is 3%. To increase basis weight by 1 gsm, only the basis weight valve is increased. As a result, the flow through headbox remains the same, but its consistency increases. For the above three situations, the process was simulated on a computer and fluctuations in gsm were evaluated to get a desired value of 40.0 GSM. The data obtained are as under -

Head Box Consistency	Backwater Consistency	Min. GSM	Max. GSM	Fluctuation (GSM)
0.85%	0.15%	48.9	49.3	0.4
0.75%	0.20%	48.6	49.2	0.6
0.65%	0.28%	48.4	50.3	1.9

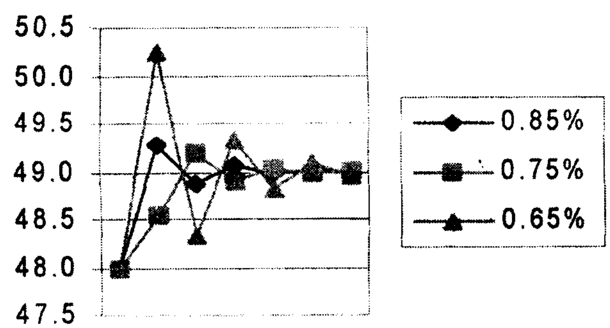

Fig. 6: Effect of Head Box Consistency on GSM Stabilization to a Newer Value.

Having a look at fig. 6, we see that the gsm stabilization also takes longer time with low headbox consistency and high backwater consistency .It should also be noted that the figures shown here are for a typical machine with a typical raw material. As the backwater consistency-headbox consistency relation is also dependent on fibre type, refining, filler content etc.; alongwith wire type, simulation should be made for different type of furnishes, freeness levels etc. for the type of wire used by the mill. In above case, we can see that the gsm fluctuation increased rapidly after reducing headbox consistency below 0.75; the mill decided to ensure that the headbox consistency remains above 0.75. After similar simulation studies with different furnishes for the different types of paper being made, it became possible to develop norms for minimum allowable headbox consistency.

Backwater Silo

Backwater silo is again a very complex system. As indicated above, approach flow alongwith wire part decides the backwater consistency .Furthermore, due to presence of dissolved air in backwater, which is again a function of backwater consistency , this starts working as a relatively lesser efficient DAF (dissolved air flotation) fibre (fines) recovery system, where, fines are removed at the top alongwith silo overflow. Due to this backwater consistency entering to fan pump decrease. In some cases the silo retention , time has been found of the same order of above mentioned systems.

Another critical aspect is the silo retention time. Commonly, the silo retention time can be calculated by dividing the silo volume with volumetric flow rate from the silo. But it may be incorrect. In many practical cases, channelling takes place from silo input to fan pump suction. These short circuit flow currents reduce the silo retention time significantly.

RESULTS AND DISCUSSION

Once the simulation results are obtained, these data can be compared to that of process data to verify the accuracy and validity of simulation. Plotting GSM versus time graphs for different time ranges, and comparing the results to those simulated ones did this. For this, the machine was operated under normal circumstances, and whenever a minor change was needed marking was made on the roll. When this roll goes to the rewinder, the markings were transferred to the reel. Such reels were cut in fixed sizes on baby cutter, and GSM was obtained by dividing the sheet weight by sheet area. As simulation

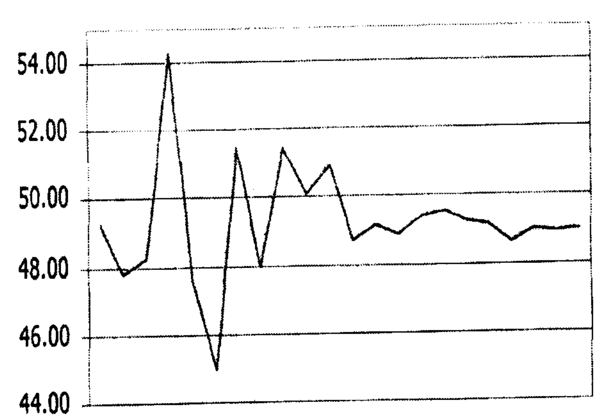

Fig. 7: Unstabilized GSM at low head Box Consistency

indicates the pulse width to be of the order of 3-4 minutes, samples were extracted after every paper length run equivalent to 30 seconds of paper machine operation. Plotting these data with time gave information about pulse frequency , from which it is possible to compute process lag for GSM control.

Fig. 7 indicates such a test case. To experimentally verify the simulation on a machine, the head box consistency was reduced to 0.6%. At this the backwater consistency was 0.32%. GSM was increased from 48 running earlier to 49 gsm. The ten minutes data was plotted against time. It indicated that it took nearly five minutes to stabilize the GSM, while there was a very high unstability of 9 gsm (±4.5 GSM) for five minutes. It was also observed that CD profile control was not easy .Later on, when several CD profiles were taken from a single roll, there was a significant difference in those readings. This indicated that the reliability of CD profile testing was getting lost.

Later on, the head box consistency was increased to 0.82%. The backwater consistency was found to be 0.18%. The gsm was increased from 47 to 49. The results are given in fig. 8, over duration of 5 minutes. Here, the GSM got stabilized within nearly two minutes. Also, the unstability was relatively lesser.

It should also be indicated that the CD profile unstability reduced drastically. As a result, it became easier for the machine operators to control CD variations in a better way. The reduction of sizing chemicals requirement, machine chest pump load, reduction in foaming in backwater silo were other advantages, which have already been discussed by other authors, so these are not specifically mentioned in this paper.

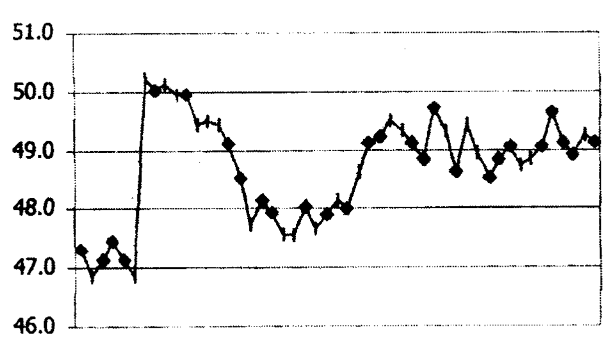

Fig. 8: Relatively stabilized GSM at increased head box consistency

Here, we may see that unstability is higher than that was predicted using the simulation above. A possible reason could be given behind this is that the drainage and backwater consistency are strongly influenced by wire table arrangement. The backwater used for sampling is a mixture of backwater generated from different table elements, which in quality (consistency) and quantity (flow rate) differs for different operating conditions. A more detailed analysis is required to simulate actual operating conditions on a computer.

CONCLUSION

On the basis of above, the head box consistency was increased and retention aid dosage was increased to get better retention and lower backwater consistency. It was observed that in most of the cases, the GSM stabilized within a very short time. Furthermore, if GSM is rapidly fluctuating, it is obvious that control in a nerrow range would be difficult. After increasing headbox consistency , it was observed that most of the rolls were maintained within ± 0.7 GSM of the desired value very easily. It must also be noted that these are the results on a machine without running a consistency or stock flow control system. This was also observed that after implementation of above process changes, the GSM related complaints reduced significantly by over 90%.

As indicated above, unstability also results in CD profile variations. It was observed that the CD profile variations reduced by more than 40% of the original ones after implementation of these changes. As obvious, it became possible to increase machine speed, and a 5-6% speed increase was made without any further modification.

REFERENCES

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