Consistency Control for Stability and Agility in Paper Machine

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ABSTRACT

The ideal paper machine should be both stable and agile. Stability allows consistent paper production with better quality. Agility is required to start up, recover from breaks, and switch production from one grade to another with a minimum of lost time and material. As speed increase, the inadequacies of traditional stock preparation and short circulation process designs or sluggish process loops are becoming more and more evident in both these areas.

In this paper, we will review the consistency control problems encountered in the traditional stock blending and sub-processes feeding the machine. Some problems can be overcome using new instrumentation and by careful design and tuning of the control systems. As well as improving the stability of the wet end, it will permit grade changes to be made much more quickly than is possible with unstable consistency lines.

WET END PROCESS

The furnish used to make paper is a complex, multi-phase mixture of various virgin and secondary fibers mixed with chemical additives and broke. Typically, the stock for each street has different fibre mix, different chemicals and additives, and has received different treatment (refining, deflaking, etc.). The properties of all these components are continually changing, leading to upsets in the process.

To make matters more complex, a significant portion of the furnish does not become paper in its first pass down the production line. The amount of this broke and white water that must be recycled varies considerably. Meeting these challenges requires a complex process. Figure 1 shows a simplified process diagram of how this fiber mixing has traditionally been handled.

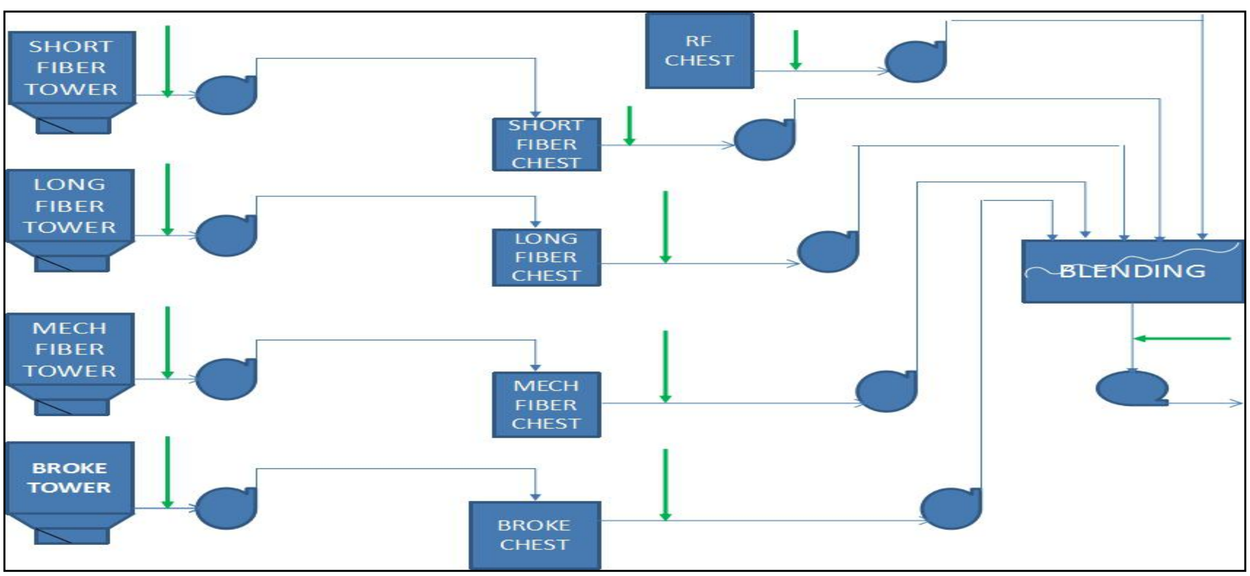

Figure 1 : Stock Prep Process Diagram

This is the very important part of the machine and can also be a source of considerable variability contribution to the weight and moisture variations.

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MASS BALANCE

Considering mass balance equation for this system shows that variations in stock flow and consistency directly impact the weight and moisture. During the normal machine run, paper makers usually ignore these fractional changes of stock consistency and stock flow variations. But Our experience and data analysis shows that fractional changes in stock consistency and speed directly impact the weight.

$$\text{Bone Dry Weight} = \frac{\text{Stock Flow} * \text{Stock Consistency} * \text{FPR} * \text{Unit Conversion}}{\text{Wire Speed} * \text{Slice Width} * 100}$$

When we troubleshoot weight variation, we ignore the FPR and Speed variations. However, for this discussion, we assume that both FPR and Speed are constant.

The fractional changes of consistency have very important and dramatic interpretations.

For example,

Stock Consistency = 3.5%
Weight = 60 gsm

If the consistency variation **+- 0.1%** (that is **3.4 to 3.6**), this would result in a change in weight of **+- 1.72** gsm (that means **58.2 to 61.8**). This source weight variation may not be able to find in any historical or process trending data.

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CASE STUDY

The process has many forward flowing and recycle streams and these provide paths for the propagation of disturbances. Broke and water are recycled from the paper machine and returned to the stock preparation area, where they are cleaned and solid material is reclaimed for re-use. Some of the recycled fibre and water can be returned to WW system

All these paths allow an upset in one location to create further upsets in other locations. If the timing is unfortunate, these disturbances can become mutually reinforcing and sustained oscillations will be created. Often the cause of an upset is far from obvious. Since there are so many paths, each with different volumes and flows, the dynamics can become very complex making troubleshooting difficult.

The first step is to minimize the upsets that could trigger this behavior. It is always better to prevent disturbances than attempt to compensate for them after the fact. Often, this requires simple attention from the operation team and maintenance of the basic instrumentation in the stock preparation area. Unfortunately, this part of the plant often receives low priority.

For instance, one prominent feature of Figure 1 is the existence of several series of large towers and chests. These are intended to reduce variability through stock mixing. When this mixing functions correctly, it has a major stabilizing influence on the process, although this is a rather expensive solution. Too often, problems like those shown in Figure 2 are seen where a improper tower consistency dilution flow calculations, improper consistency dilution pressure, sticky blend chest level valves or consistency valves causes cyclic variation in the consistency feeding to machinel. Interactions with other level, flow and consistency controls cause this disturbance to be amplified as it propagates upstream.

BEFORE CONSISTENCY SURVEY AND TUNING

The following example was taken from a machine that was experiencing significant weight variation but the source could not be seen from the dcs trends.

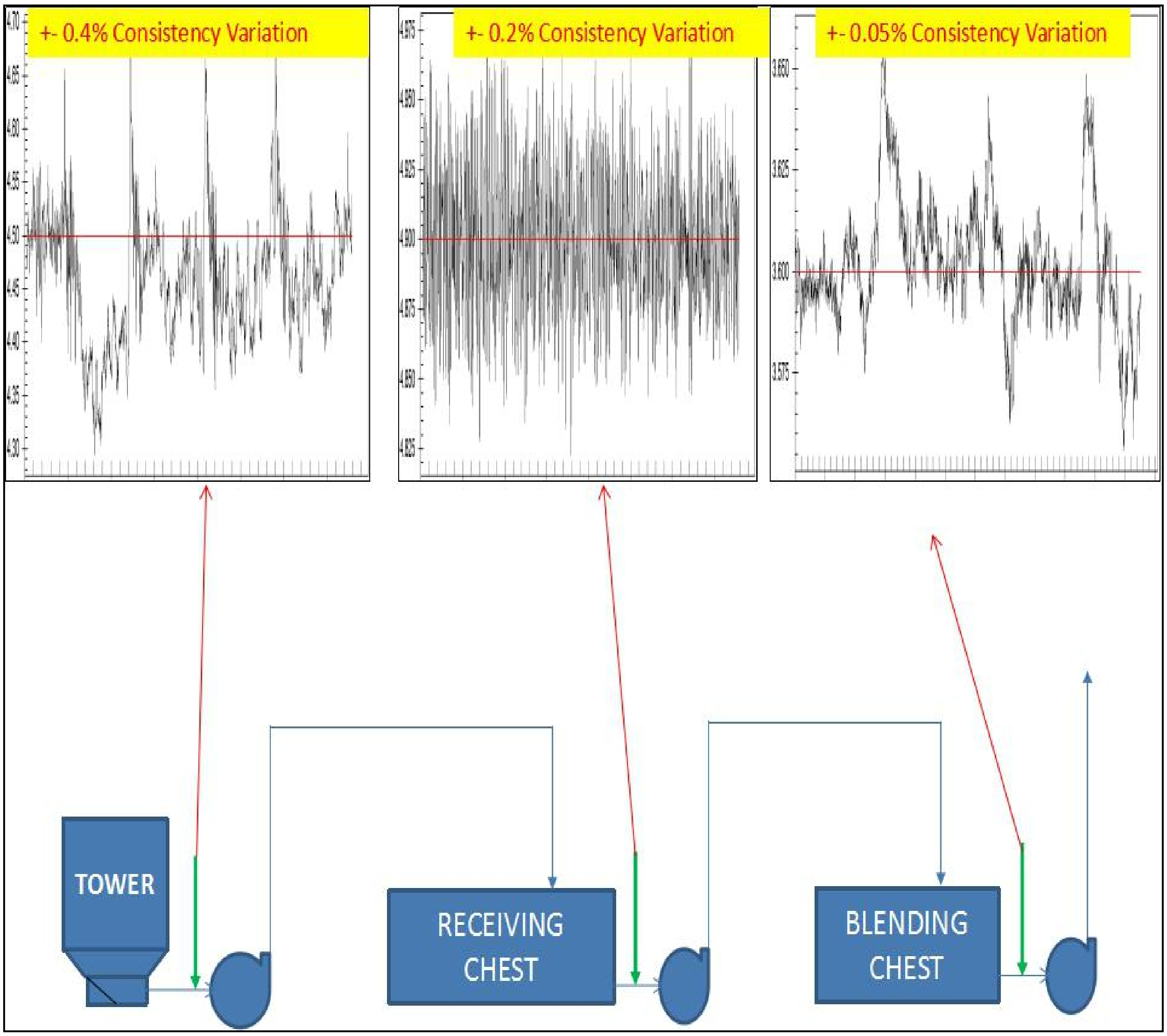

Figure 2 : Consistency Trend from Tower to Blending Chest Before Tuning

The above figure shows that the tower consistency variation is about 0.8% peak to peak. This variation was further come down to 0.4% peak to peak in receiving chest which is due to its large tower and chest capacity and better agitation. Blending chest variation was 0.1% which was causing the weight variation as shown Figure 4.

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This tower consistency cyclic variation happended due to the improper consistency dilution water flow calculations. This variaiton was disappered after solving the tower dilution water flow control logic as shown below in Figure-3

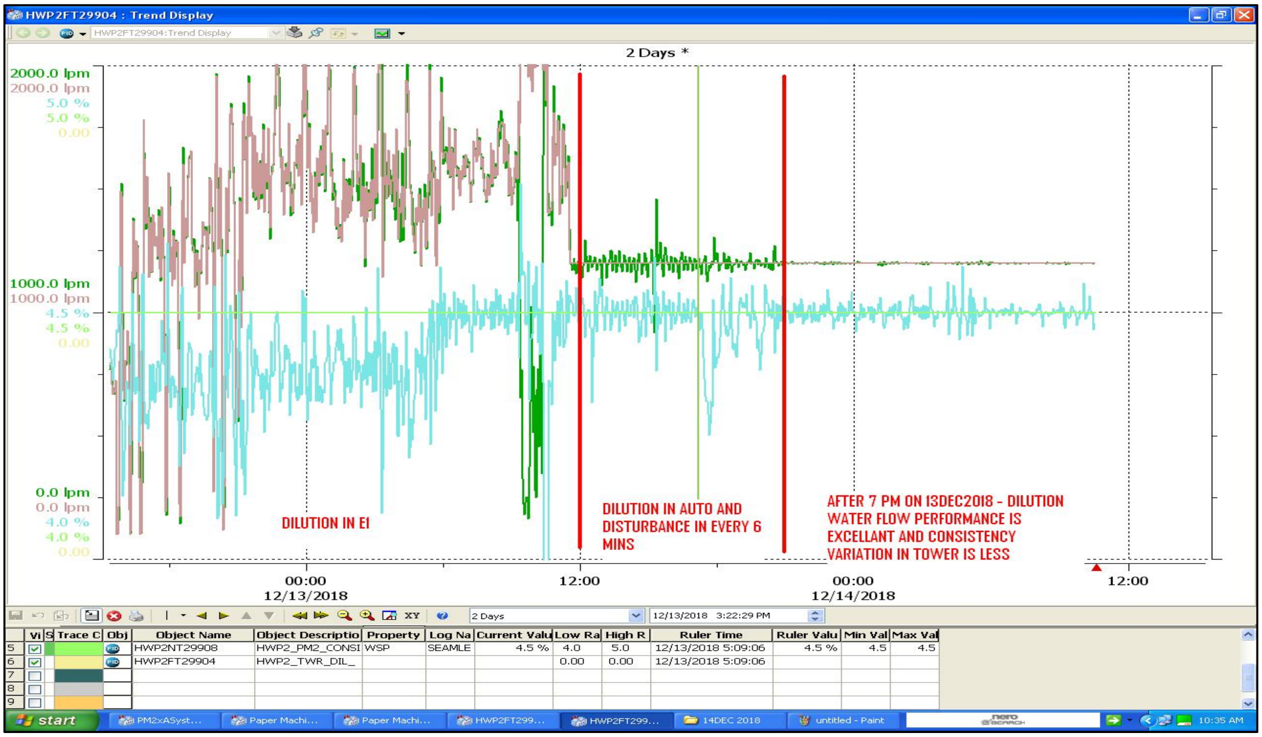

Figure 3 : Tower consistency variation due to Dilution water flow variations

Blending chest variation was 0.1% which was causing the weight variation as shown Figure 4

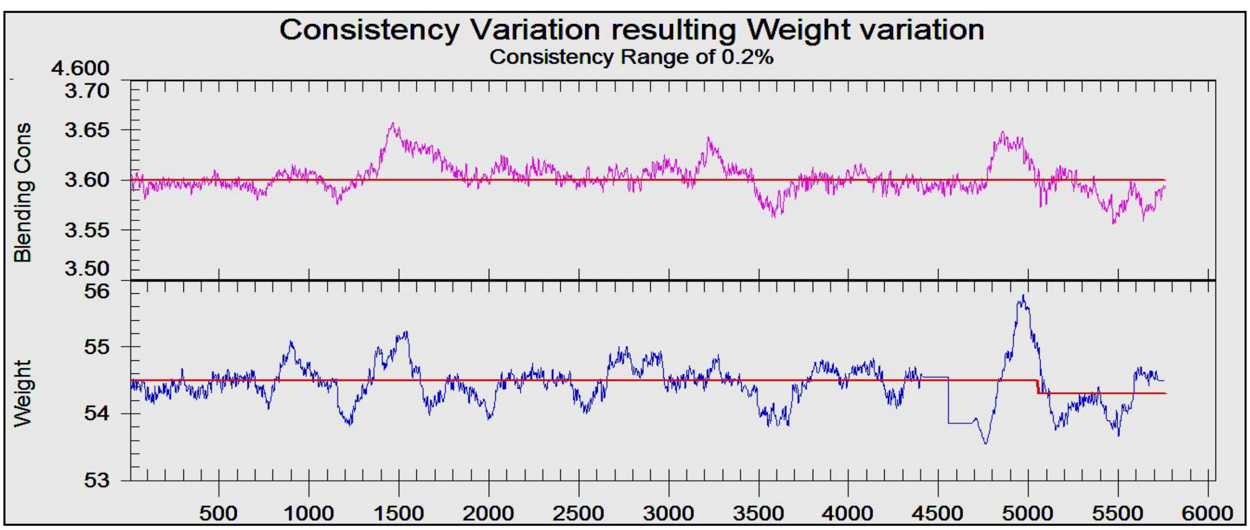

Figure 4 : Blending Consistency Variation resulting the weight variation

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TROUBLESHOOTING TABLE

There are several issues to be considered and corrected for troubleshooting the process varations. In order to help narrow down the issues list, we follow the below table which shows that common problem areas.

	Area	Stock Flow	Stock Consistency	Weight	Moisture
Transmitter	Type		X		
	Installation	X	X		
	Calibration	X	X	X	X
	Filter	X	X		
Signal Conditioning	Decimal Points	X		X	X
	Filter	X	X		
	Dead Band	x	x		
Valve	Size	X			
	Type	X	X		
	Precision	X			
	Positioner	X			
Control	Tuning	x	x		
	Execution Rate	X			
	Dead Time	X	X		
	Delay				
Process	Disturbance	x	x		
	Design	X			
	Oscillations				

After plotting this data together, it became very clear that process variations can come from a wide range of places.

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AFTER CONSISTENCY SURVEY AND TUNING

The below figure shows that the tower consistency variation has come down to 0.2% peak to peak after changing the consistency tower dilution flow logic and better tuning of the consistency loop. This variation was further come down to 0.1% peak to peak in receiving chest. Blending chest variation was 0.01% which stabilized the weight and moisture variation as shown in Figure 5 and 6.

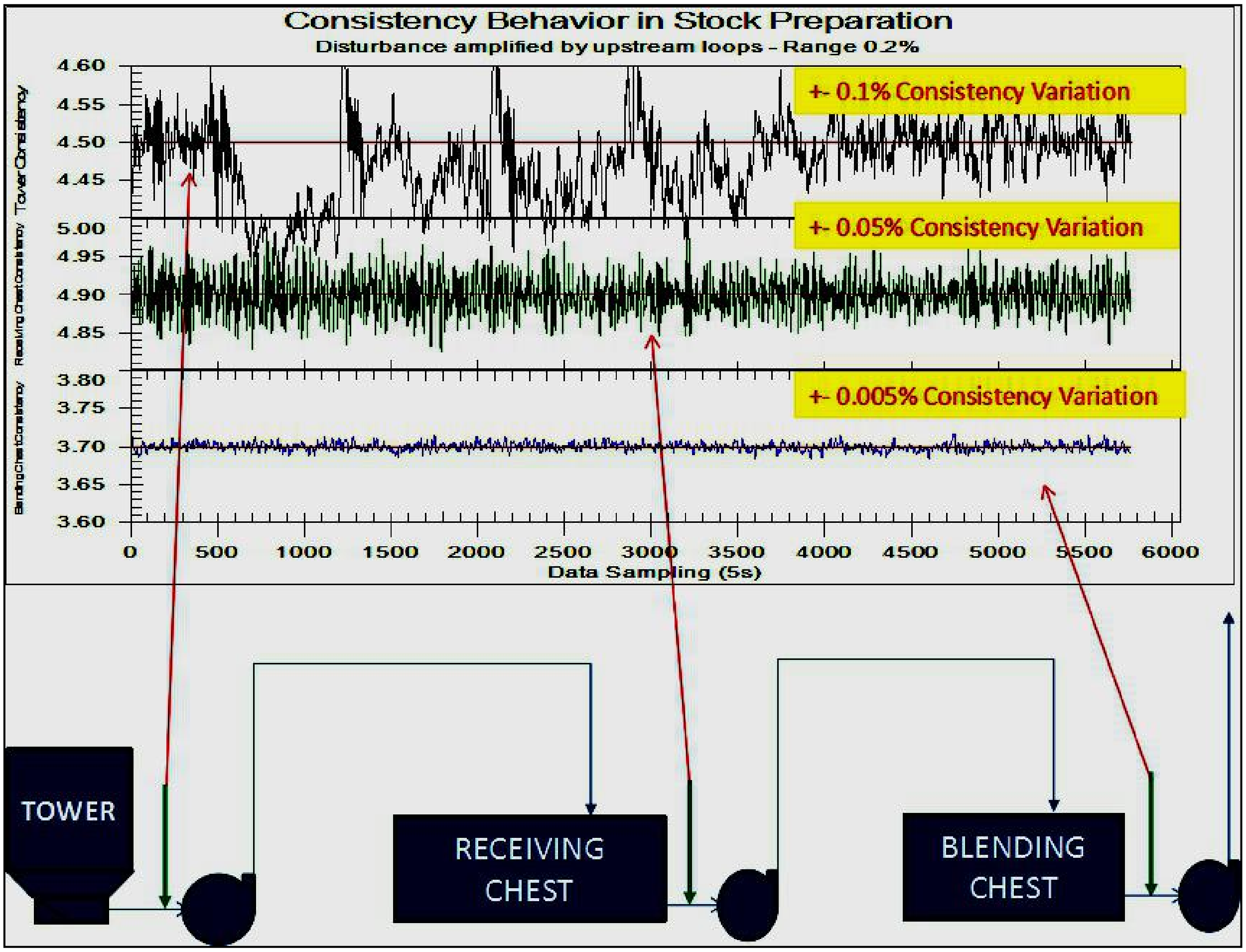

Figure 5 : Consistency Trend from Tower to Blending Chest after Tuning

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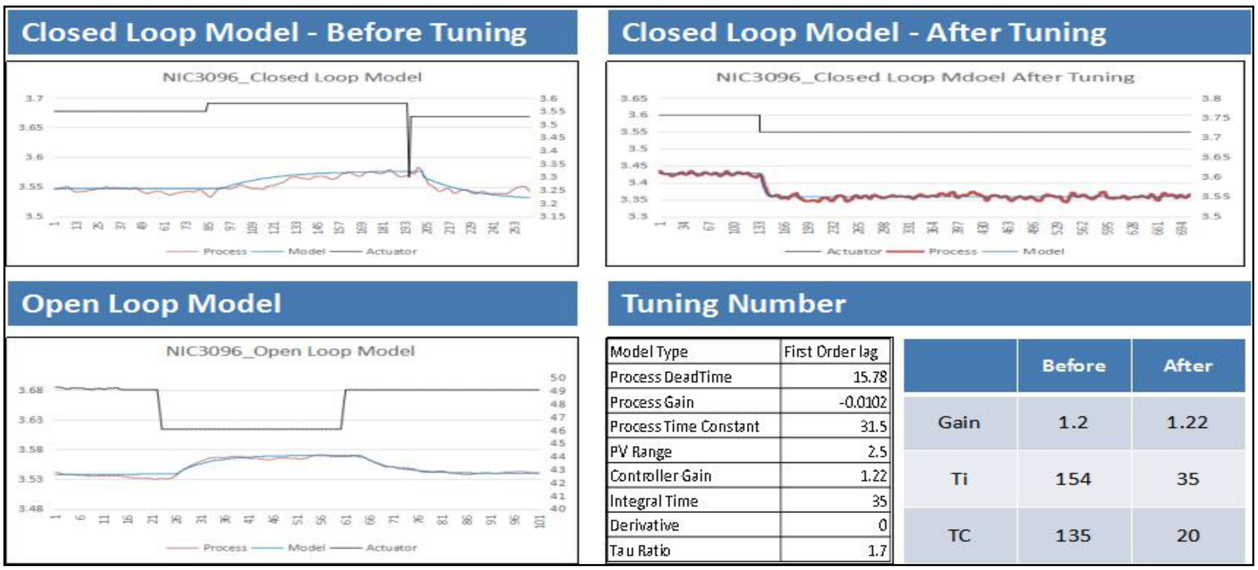
BUMP TEST RESULT

The bottom four pictures show the bump test result of Blending consistency. The bump test and tuning of this loop was dramatically improved this loop performance. Both steady state index and transition index has improved by 80%. The bottom right figure is showing the tuning number and its improvement. The TC (Closed loop Time Constant) has reduced from 135s to 20s which is showing the transition index improvement.



Model Type	First Order lag
Process DeadTime	15.78
Process Gain	-0.0102
Process Time Constant	31.5
PV Range	2.5
Controller Gain	1.22
Integral Time	35
Derivative	0
Tau Ratio	1.7

	Before	After
Gain	1.2	1.22
Ti	154	35
TC	135	20

Figure 6 : Blending Chest Consistency Process Model and Tuning Number

Blending chest variation was 0.01% which stabilized the weight variation by 60% as shown Figure 7

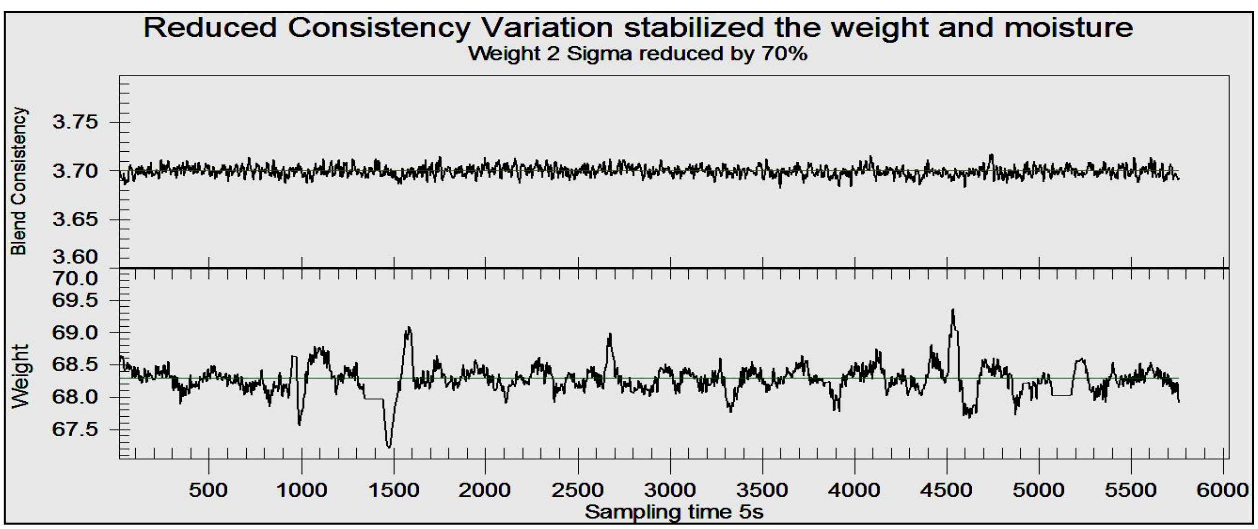


Figure 7 : Reduced Blending Consistency Variation stabilize weight variation (8 Hrs data)

Figure 8 : Reduced Blending Consistency Variation stabilize weight variation (2 Sigma)

CONCLUSION

The major issues for the instability of the Paper Machine are identified as Wet end variability, which was causing the product variability and also taking longer time to stabilize after sheet breaks. The wet end has been stabilized by identifying and resolving problems, such as stock flow variations, consistency variations, chemical flow variations and slow QCS response of the control loops etc..

Steps taken to stabilize the consistency from tower to blending chest paid off in many ways. A few of them are as follows

- Reduced weight variability
- Reduced Moisture vairability
- Reduced Ash variability
- Increased Operator Confidence
- Reduced Grade Change time