ISSN: 0379-5462
IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 30, E2, 2018, pp.6-13

Case Study of Consistent Pulp Quality with Optimization Utilizing Advance Algorithms

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Abstract: *To achieve consistent quality of pulp with optimum production, each and every control loop of the process has gone through monitoring with the help of VPM (Valve position monitoring) algorithm which reveals the best operating point of the process in the installed vicinity. And this was followed by implementation of logic utilizing VPC (Valve position control) algorithm to maintain the process operating on optimum performance points. Areas where traditional instrumentation is not workable, has been substituted with other technologies rarely utilized in process industry for measurement and control of process. It includes use of Machine Vision based control system at Continuous Digester Pin Feeder Section to maintain Alkali charge in accordance with available variable raw material feed rate.*

Key words: Consistent Pulp Quality, Valve Position Monitoring Algorithm, Indicator system

Background

For any business to remain sustainable four essential components are:

1. Availability of renewable/sustainable Raw material
2. Higher Production with Consistent Quality
3. Suitable & Sustainable market
4. Continuous focus & improvement of Environment

Yash Papers Limited is 100% renewable agro based integrated Pulp & Paper manufacturing unit being situated at the centre of agricultural belt of North East Uttar Pradesh, so raw material is easily available.
We are technologically up gradating our process & system to increase our productivity day by day.
Our bagasse fibre is suitable for making various grades of paper for different packing applications. While focusing on our customers need and feedback for continuous improvement, we are always conscious for environmental impact of all our activities.
To maintain our quality parameters within targeted range, we focused on upgrading skills and knowledge of our shop floor peoples. At the same time, we also upgraded operational automation to enhance process efficiency, product quality and utilization of capacity.

Objective

With our objective to achieve growth based on sustainability, we focused on achieving consistent pulp quality by optimized control of process which in turn reduces manufacturing cost through optimum utilization of resource (fibre, chemicals, energy & water).

Methodology (Optimization)

Concept Evaluation

Ideally, the plant equipment should be operating at their design values and give the better performance in view of efficiency, quality and production rate. However, in practical, over a period of plant run there are many factors which deviates the operating point of various equipment from its design point. The reason may be change of control valve, pumps & motor in course of maintenance, change in raw material and final product from design stage consideration, modification of pipe lines, and change in available ID of pipe line due deposits on pipe internal wall, addition of equipment and process skids, etc. All these things might cause inefficient process with variation in quality and production.

Yet, again the production rate being major driving factor in plant operations; it is observed that most of the time the plant is operated at point where quality could not be maintained. Doubtless, this also leads to a situation where plant is running for fewer hours in a day with exceeding the expected values.

It was always a doubt and prediction from operating floor personals that if plant will be operated for required consistent quality production, the production rate will get decreased. The prediction was based on few process restrictions of upward and downward processes.

Earlier System

The pulp mill is being operated through Honeywell PKS-Experian DCS since its incorporation in 2006-2007. Operational logics were built as per process requirement. It includes normal PID Control Loops, Cascade PID Control Loops, Feed-Forward PID Control Loops and other interlocks.

It could be normally observed that there are several loops in which the final regulatory control element which may include control valve, actuators, VFD operated pump, etc. are either operating at higher side or high limit of control output or at very low value or low limits throughout entire production range.

Also, the production rate is mostly decided by the plant operator based on demand from downward/upward process and in-plant buffer stock. It causes plant running at either very low or very high production rate in compare to the plant's actual best operating range.

Optimization Activity

In any process moving from Isolation to Integration of various sub-sections will results the better process operation, consistent quality and optimum production. To achieve this migration from isolated control to integrated control, we have implemented supervisory control on higher level of existing control system which monitors the plant condition and resources utilization and takes necessary action to optimize the plant production rate in complete controlled manner.

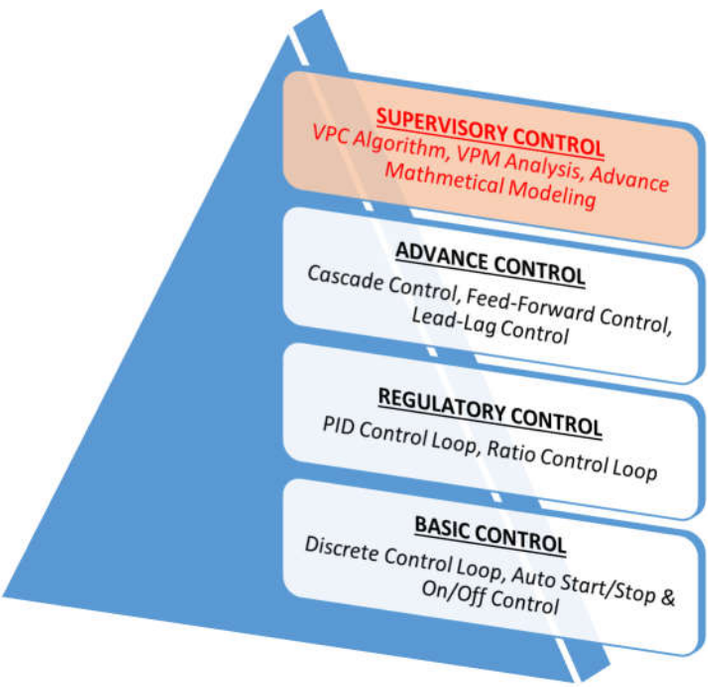

Figure 1-Visualization of Control Levels

The supervisory control could be any system comprising of any third-party Hardware/Software based system, Software based system or even logics within the existing control system which can generate various supervisory control output to govern the Advance, Regulatory and Basic control loops for optimization of the process.

As opposed to process personals assumption that production rate get affected if quality production will be deciding factor for plant operation; the plant has achieved its ever higher production rate of ***3962 Tons*** after implementation of optimization logics.

VPC Algorithm

Here at Yash Papers Limited, one of the major roles in supervisory control is a tool we developed and called VPC (Valve Position Control) algorithm to implement predictive control in existing control logic. It should not be confused with Control Valve & Actuator position feedback monitoring. It could be any of SISO/MISO/SIMO/MIMO control scheme whose input (PV) is control output of various loops and output (OP) is the optimized target production rate of system or sub-system

under consideration. The implementation is done using DCS PID blocks, SFCs and logic build in external supervisory control system as per requirement.

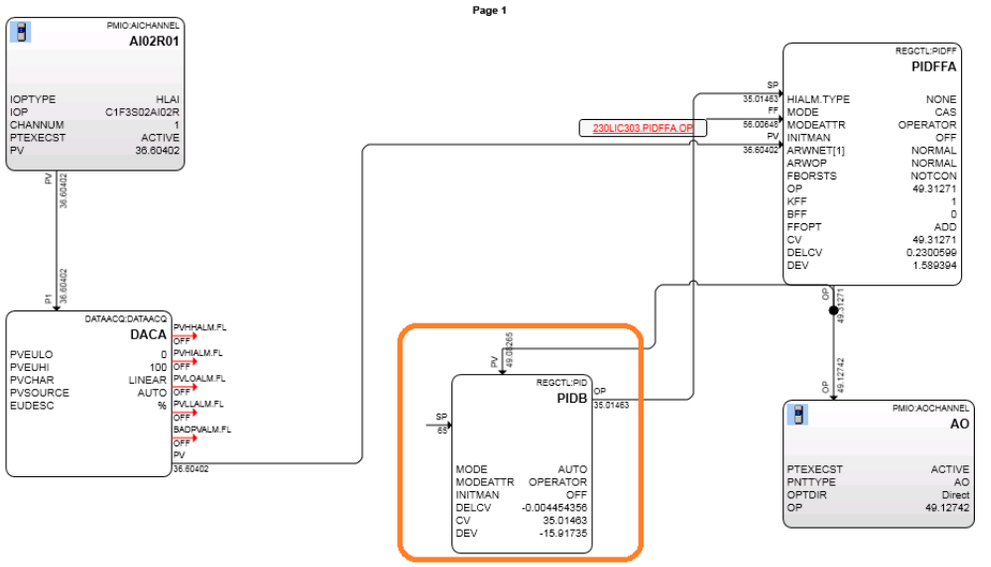

Figure 2-Simplest form of VPC implementation using PID Block

The concept evolves from the monitoring of process which reveals that the best quality could be achieved only when all of the equipment is operating within their respective optimum operating zone. If any equipment reached to the limit beyond which, the pulp quality parameters like refining/washing, pH or efficiency of equipment like shives removal, dirt or other contaminants removal from cleaning equipment; the production rate should be restricted until the restricted equipment come back to best operating zone.

It is not possible and in most cases not feasible to install measuring instrument at every line/equipment. The VPC algorithm gives an effective control without any investment on field instrument and associated control hardware interface. The control loop output (which in turn operates the control valve or VFD operated pump) is one of the key parameter to derive weather the process has reached to its limit or not. Based on this input it can be decided to restrict/ decrease the production rate for maintaining the quality production as well as the same input also takes decision to increases the quality production rate if margins are available.

VPM Analysis

Apart from implementation of VPC Algorithm for control purpose, to ensure that the plant is running within controlled zone there must be a system which capture and store key parameter and based on various statistical methods could provide information for recommended corrective action. For this, again control loop outputs needs to be stored in database for later analysis utilizing various tools available in market or develop custom analysis module. This process is under implementation at site by next few months the results will start coming to further take the action and provide controllability report of the process.

Utilization of above algorithm at Mill

BSW & Decker Section: The discrete control loops of various process is already available and most of the loops are working in auto mode and set-point of loops are decided by plant operator/supervisor based on availability of final pulp at storage tower and availability of pulp from Digester. We have implemented logic to monitor the operating point of individual equipment like Pressure Screen, Decker Washer, TDR and developed logic to control their operation within best operating zone. The best operating zone has been tested separately by a team of process, quality and instrumentation.

The simplest VPC logic is equal or like one shown in Figure-3. In this logic the PIDFFA bloc (a Feed Forward PID Block) is already there for control of a given process (in picture it was from seal tank level control of BSW section). The output of this block regulated a Control valve in field which transfers washing liquor from one stage to another. Before VPC control, the transfer rate was entirely depending upon the level of seal tank and position of previous stage control valve (control valve is feed-forward element). This logic doesn't care about the condition of next section wash liquor amount. It causes lower or higher amount of wash liquor at corresponding stages which in turn causes washing inefficiencies and soda loss. To minimize the effect, the earlier logic was having high and low limit of PID output but VPM analysis reveals that most of the time control output are clamped at that high or low limit only. Here, we used the VPC algorithm to control the rate of

minimum/maximum transfer to other section in a gradual manner to achieve best washing efficiencies and reduction in soda loss; as well as the excess soda which was carried with pulp for bleaching stage has also been controlled which in turn reflected in reduction in bleaching chemical load.

Apart from this simplest PID based VPC logic where only one element needs to be controlled, we had utilized this algorithm on the loops which are affected by various another parameter or effecting various other parameter; utilizing SFC based VPC logic to limit the equipment operation within the best operating zone.

Methodology (Innovation)

Use of Non Traditional Instrumentation

Instrumentation is widely being used by various kinds of industries including R&D, Lab, Process, Assembly, Packaging, Distribution, etc. Based on the usages there are various kind of instruments which are developed for specific industry type. The Pulp & Paper Industry comes under process industry and most of the instrumentation used here from the process industry instrumentation segments. However, there might be various instruments available for other industry which could be utilized for Pulp & Paper industry process control where traditional instrument implementation is not feasible.

At Yash Papers, we are ready to explore external gateways for non-traditional technologies to address its various quality and sustainability requirement. In this course we have used Machine Vision Technology which is already a proven technology being used in Automobile, Assembly and Electronics Industries. This technology is used for monitoring of raw material feed to continuous digester and based on the feed rate, controlling of Alkali charge to the digester.

Mechanical System

For raw material feeding and regulation to continuous digester Pin Drum Feeder is used. The Pin Drum Feeder is metering equipment used at various industries for feed regulation. In combination with Cross Screw Conveyor and Excess Conveyors It is also best suited for feed regulation at Continuous Digester. As per its design, the pin drum feeder output could be calculated accurately for any particular feed provided the shoot level is constant. If soot level varies then the Pin Feeder output also varies and calculated output based on RPM and Load may not accurate.

Earlier System

The pin drum feeder RPM is set by the Digester operator based on required production rate. Raw material feed is being calculated from Pin Drum Feeder RPM and Load. Due to unregulated feed of raw material of and/or operation of Wet washing equipment it is not possible to maintain constant feed to the pin feeder.

The caustic feed was regulated based on raw material feed calculated from Pin Drum Feeder RPM and Load. The drawback was inaccurate raw material feed calculation at the time when pin drum feeder shoot level varies while the load of pin drum feeder doesn't reflect real change due to its dead load. For example, if there is fewer raw materials available or even no raw material available while pin feeder is running the calculation shows sufficient amount due to dead load.

Use of Machine Vision System

The vision system has been used on Continuous Digester to achieve consistent quality of cooked pulp from Digester. We have investigated the cause of variation and developed the control system accordingly to minimise the variation. Instead of doing backward control using measurement at digester output and then making corrective action, we tried to implement pre-act control algorithms, in which the input factors of any process which causes output variation are controlled at process feed point. Below is the detail of procedure. So rather measurement of actual kappa number at outlet we started our project with analysing factors for variation in kappa:

Kappa variation	α	variation in Cooking Temperature	(1)
Kappa variation	α	Variation in Cooking Time	(2)
Kappa variation	α	Variation in Bath Ratio	(3)

Here at our mill the Cooking Temperature and Cooking Time is well controlled by the DCS. Hence, we further analysed the Eq. (3).

Variation in Bath Ratio	α	Variation in Raw Material Moisture	(4)
Variation in Bath Ratio	α	Variation in Caustic Feed	(5)
Variation in Bath Ratio	α	Variation in Raw Material Feed	(6)

Again, we noticed that the Moisture in Raw material at digester feeding and Caustic feeding is under control. Caustic feed control loop is in cascade with respect to the Raw Material Feed, which is being derived from Pin Feeder RPM and Pin Feeder Load using following equation:

Raw Material Feed α Pin Feeder RPM (7)
Raw Material Feed α Pin Feeder Load (8)
Raw Material Feed = k * (Pin Feeder Load – Dead Load) * Pin Feeder RPM (9)

Where, k is a correction factor which is derived through physical verification of raw material feed.

As we know that due to design of Pin Feeder Based Metering device the blanket over pin feeder soot plays important role. The output from pin feeder will be accurately measured and controlled if the pin feeder shoot is compact. We noticed that this is not case at Mill due to uneven supply of raw material from raw material storage. The digester operators are used to keep the pin feeder at higher side so that the maximum feed can be handled. It causes wrong measurement of raw material feed to the digester and in turn the bath ratio is not correct.

We have then installed Vision monitoring system on pin feeder section and developed the logic to maintain the pin feeder soot. In this control system, the vision system gives information to the existing DCS regarding availability of raw material and based on that information the DCS regulates the Pin Feeder RPM. Now, since the pin feeder soot is compact the raw material feed from Eq. (9) gives correct measurement and Bath Ratio got maintained. It provides control over kappa variation as well as overall process improvement in Pulp mill at BSW stage, Cleaning stage and Bleaching stage in term of reduction in soda loss, WBL generation, reduction in caustic consumption, chlorine consumption, etc.

The Machine vision system is not a conventional system to control raw material feeding. We adopted this technology from Automobile Industry where Machine vision system is used for various type of measurement and control.

Here at YPL, the machine vision system monitors the raw material availability and regulates the Pin Drum Feeder RPM to maintain constant pin feeder shoot level. By doing so, accurate raw material feed could be realised.

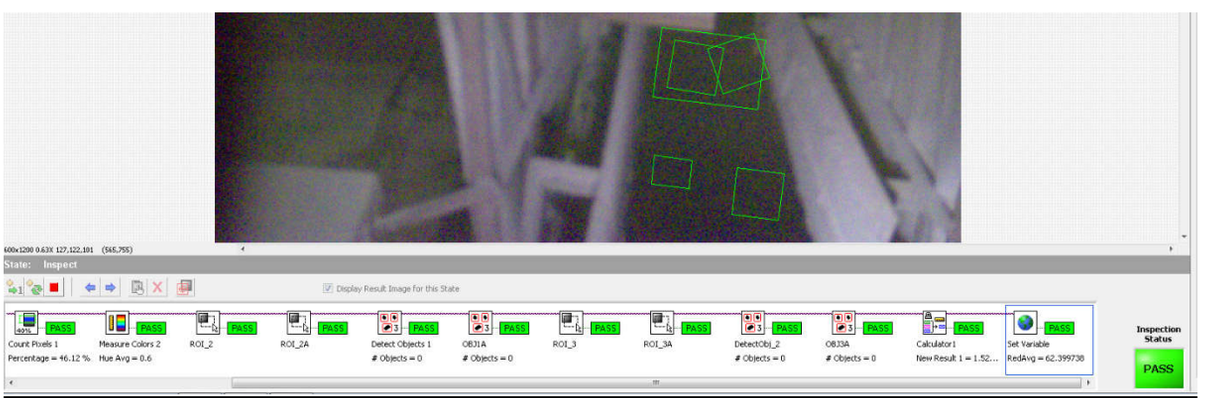

Figure 3- Vision based control system

Achievement

As stated above the caustic flow is controlled based on raw material feed quantity. Earlier due to inaccurate measurement of Raw Material quantity, the caustic feed was also not correct. Due to which there are kappa variation as well as excess caustic consumption.

After implementation of Machine Vision system, the caustic is controlled as per actual raw material feed to digester.

Project Highlight

Note

Investment	**-**	**1.25 Cr.**
ROI	**-**	**20 Months**

The above ROI doesn't include monetary gain from quality improvement and reduction in rejection of poor quality production

Results

CONTINUOUS DIGESTER:

1. Stability achieved in Kappa number
2. Reduction in Alkali Charge
3. Improvement in Yield
4. Reduction in operation of Blow Back Cylinder
5. CBD Level Control Valve over shooting reduced.

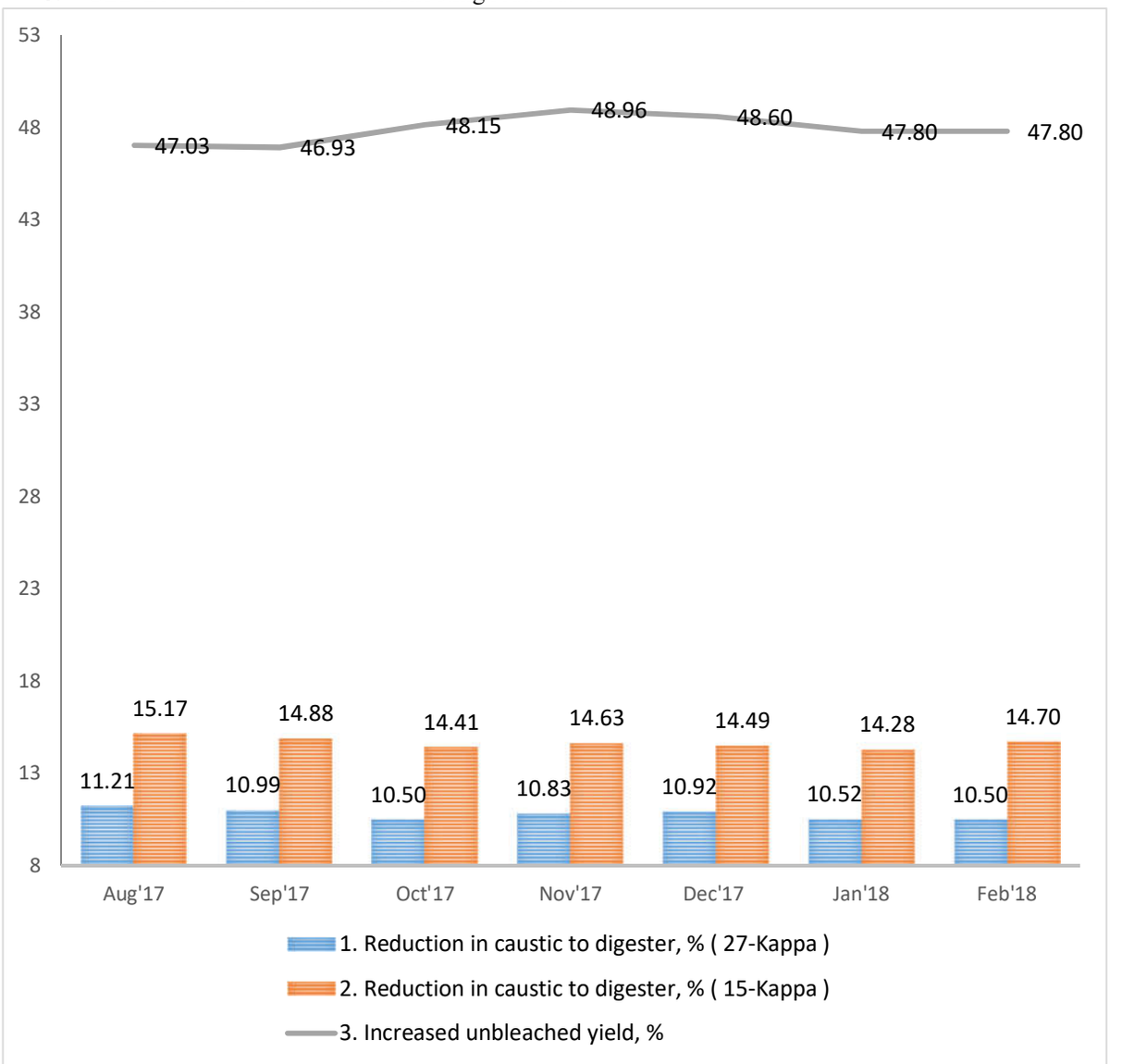

Figure 4-Improvement in Continuous Digester Section

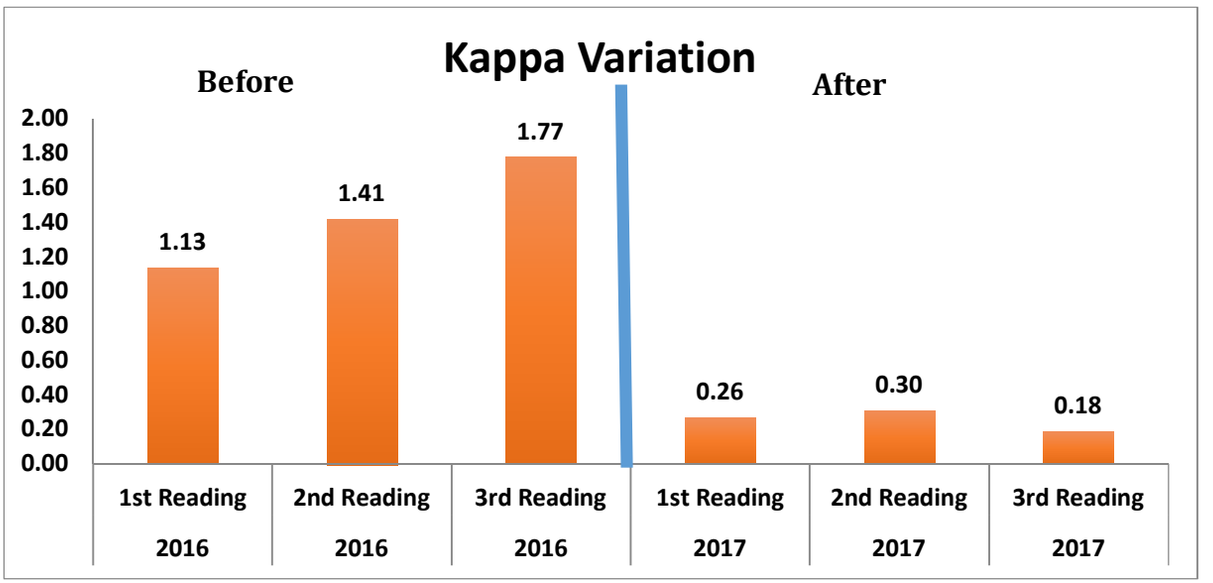

Figure 5- Kappa variation comparision

Reading of 2016 is without Vision system

Reading of 2017 is with implementation of Vision system of same month

WASHING AND CLEANING

1. Reduction in Soda Loss
2. WBL generation optimized
3. Reduction in pH variation at Decker O/L
4. SRE Control at TDR of all Pulp Mills
5. Zero complaint due to Shives

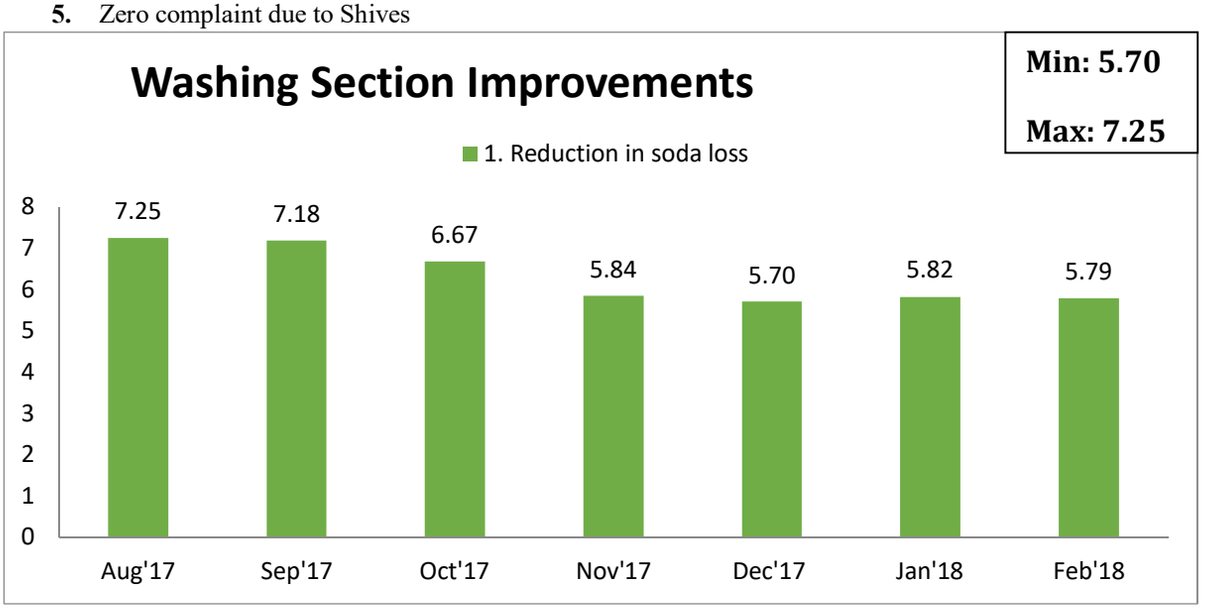

Figure 6- Improvement at Washing Section

BLEACHING SECTION

1. Reduction of Chlorine Consumption
2. Brightness Optimization

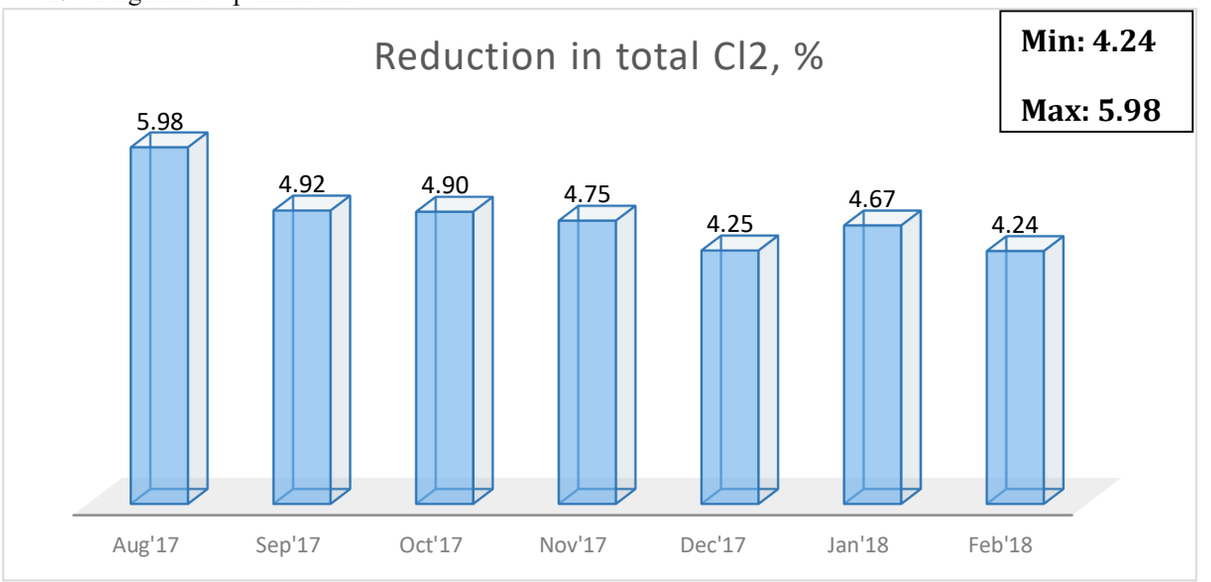

Figure 7- Improvement at Bleaching Section

Note

The task of optimization and use of machine vision system has been started from Sep-17 and got effective from Oct-17 & till Dec-17 has gone implemented in all sections of the Pulp Mill.

Conclusion

Efforts at Yash Papers Limited has proved that continuous focus by core team can help them to achieve consistent product quality from existing resources and also reduce the cost of production besides finding in-house solutions for environmental challenges. This in true sense will lead to sustainability transformation.

This is all possible with affordable investment with attractive payback.

Acknowledgement

The authors are thankful to Yash Papers Limited management for giving permission to present & publish this paper. We also express thanks to Mr. Vinay Kumar Mishra, Mr. Ram Kumar, Mr. Rizwan Akhtar, Mr. Anoop Sharma, Mr. Vishnu Kant Rai, Mr. Santosh Yadav & Mr. Suresh Gupta for their valuable help in process study, analysis &execution work.