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Minimize Sheet Breaks in Paper Machine using Data Analytics

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Abstract:

Sheet-break is a long-standing problem in the paper industry and are of major concern because they diminish the reliability and efficiency of the paper machine. This paper is concerned with the analysis of process data to diagnose causes of sheet-breaks and implementation of corresponding solutions to reduce down times due to sheet breaks. Advanced data analytics techniques were used to understand and predict an impending process failure (Sheet Breaks) in a paper machine. Real world data from operating paper machines was used to demonstrate the efficacy of the data analytics methods in successfully identifying the causes of sheets breaks in paper machines.

As paper making process is subject to external disturbances, operational changes and frequent interruptions, pre-processing of the data played an important role in getting consistent results. Novel techniques were used for data selection, screening and analysis. Data analysis and visualization coupled with the deep knowledge of the paper technology were used for diagnosis of root causes of sheet-breaks. Several operational changes were recommended and implemented in the process resulting in significantly reduced sheet-breaks. Key Performance Indicators calculated before and after the implementation of the recommendations show significant economic gains as a result of the application of data analytics to minimize sheet breaks in paper mills.

Key word - *Data Driven Analysis, Machine learning, Advanced Data Analytics, Sheet breaks, Fault detection, Process monitoring*

Introduction

In today's fast-evolving technological landscape, integrated advanced data analytics solutions are leading the way in transforming the pulp and paper industry. The traditionally conservative paper industry is getting empowered to leap into the future with data analytics tools and techniques that offer unprecedented efficiency, quality, and decision-making capabilities.

Sheet-break is a significant contributor to lost market opportunity as well as increased downtime and greater operating expenses. Typical down time due to a single sheet break in a paper machine producing 800 TPD of writing and printing paper is about 15 mins. On average 50 sheet breaks occur in a month leading to 12 hours of down time and lost production approximately 500 Tons per month. Additionally off grade product is also produced during the recovery time leading to additional economic loss. Thus, Sheet breaks play a major role in the overall performance of paper mills. Quick identification of the causes of the sheet breaks and implementation of the corresponding corrective actions bring attractive economic benefits to paper mills.

Sheet breaks in a paper machine are activated by a wide variety of factors, making the root cause difficult to identify. Before the advent of the advanced automation systems, mill have to diagnose sheet breaks manually. Even with the availability of various measurements from DCS, QCS, Drives and Web inspection systems, it is difficult to include all the correlations from different process areas and determine interactions without assistance from suitable data analytics techniques and tools.

Some of the causes of sheet-break build up slowly ultimately leading to sheet-breaks while other causes are quite abrupt. The abrupt faults generally come without any prior indication and are often difficult to detect in advance. So, suitable techniques need to be adopted so that most of the issues are identified and solved over a longer period of time.

METHODOLOGY

The developed data analytics methodology includes (i) Collection, (ii) Preprocessing and (iii) Analysis

Data collection:

Typical Paper mill involves several hundreds of measurements available from various sub

systems such as DCS, QCS, Drives, Laboratory Systems, Condition monitoring, Reel Reposts, Equipment as shown in Figure 1. The types of data collected include time series process data like flow, temperature, pressure, quality, offline lab data, video images, alarms and events data, Reel Reports etc. Suitable data logger software tools are used to collect data from various sub systems through OPC or any other applicable proprietary data protocols. The collected data can be stored either in an on-site system or in cloud based system. The data needs to be collected for a long duration to cover various operating scenarios involving different grades and operating conditions.

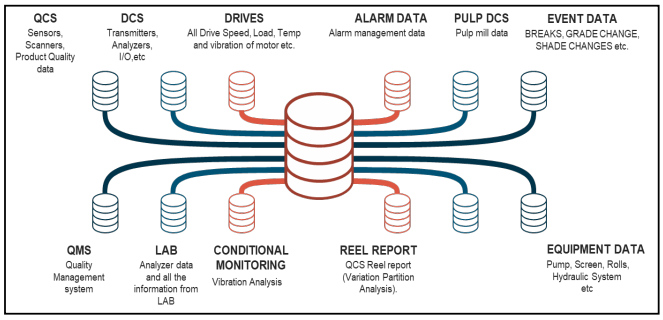

Figure 1 – Collection

Data Preprocessing:

The huge amount of data collected from various sub systems needs to pre-processed to get meaningful results from data analytics. It is important for any data-based analysis to ensure that data truly represent the different events of the process. In this analysis we used different qualitative and quantitative measures to investigate the data quality. Figure 2 shows the approach used in pre-processing of the data relate to paper machine. Equipment data such as speed, vibrations, process parameters, quality variation data, reel reports data are amenable to quantitative analysis by various data analytics techniques.

For example, quantization factor was used to detect any sensor resolution problem, compression factor to detect loss of information during the archiving, etc. Based on the data quality analysis carried out as part of the preprocessing, some of the variables were deemed unsuitable for inclusion in further analysis by the advanced data analytics techniques. Information and data related broke, pulp strength, Water quality, pitch and precipitates, microbiological issues, dirt and holes information is available offline and was used as part of the deep paper making process knowledge during integrated advanced data analysis to identify the causes for sheet breaks.

Data Analysis

Unique method of analysis was adopted to characterize and identify the root cause for the sheet break in a paper machine. It consists of various modules to provide a holistic view of the problems affecting the paper making. The modules are:

- Drives analysis to identify issues related to high load/tension
- Process variability analysis to statistically identify abnormalities
- Paper machine and stock approach system interaction analysis
- Operating parameters analysis to identify the ideal thresholds for the 'BEST RUN' period of the all the grades
- Alarms & VPA report analysis
- Equipment problems (Sensor, valve, pump, actuators, screen, centricleaner etc.)

The Figure 2 shows the data analysis methods. Advanced data analytics techniques such as auto correlation, cross-correlation, Power Spectrum, Non-linearity Index, Oscillation Index, Valve stiction Index, Data Compression Factor, Quantization, Spikes/Noise Index etc. were used as part of advanced data analytics techniques. Results obtained from these quantitative data analysis methods were used along with the offline data from laboratory and qualitative information from visual examination of the sheets breaks, squirt jam, pulp falling etc. to identify the causes for sheet breaks. Expert knowledge of the paper making process helped in interpreting the sheet breaks and the corrective actions to be implemented to avoid the unscheduled downtimes in the paper machine.

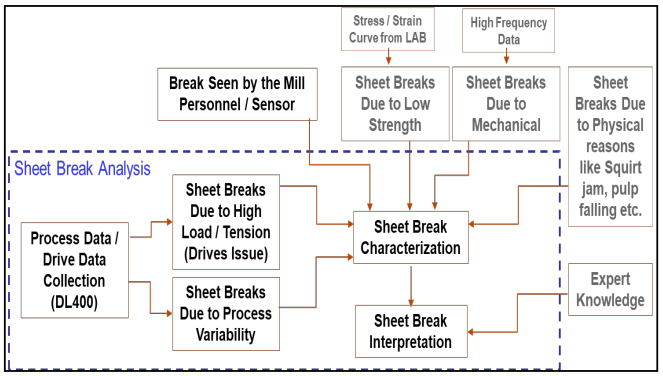

Figure 2 – Analysis Methodology

Data are available for the issues which is showing in figure-3 in blue, can be analyzed with the various techniques as shown in the paper.

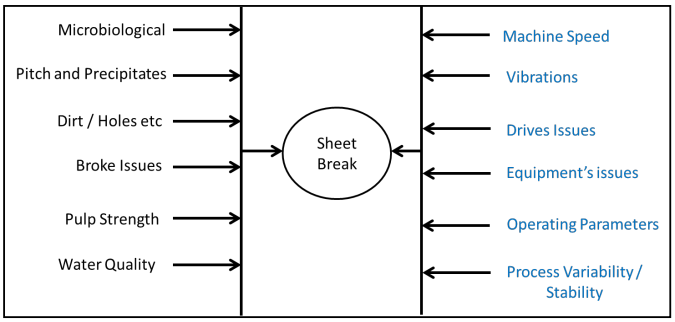

Figure 3 – Preprocessing based on issues

Generic Problem of Dead Times with sheet break analysis

The significant dead times that exist in a papermaking system plays significant challenge in process control and sheet break analysis. Fig. 4 illustrates a typical challenge.

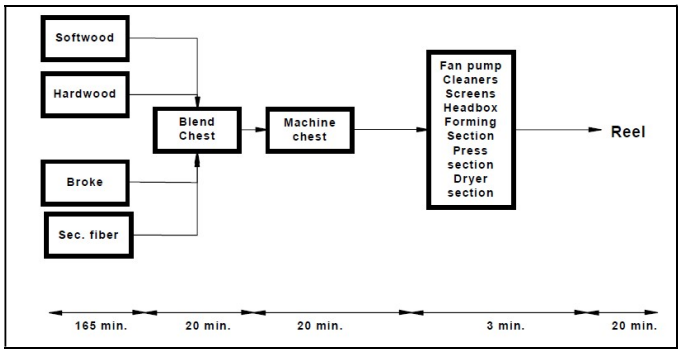

Figure 4 – Typical chest residence times across machine

It can be inferred from the figure that a disturbance in any of fiber supply chests might not appear in the produced paper for over three hours. During that time the operator will be unaware that anything has occurred and the system will fill with problem stock. With the above time lag, we calculate & interpret the breaks.

FINDINGS

Implementation of the integrated advanced data analysis method has resulted in identifying several causes for sheet breaks and these results are presented in this section.

Process Variability

Variations in the process parameters has resulted in sheet breaks. Figure 5 shows that Sheet break occurred when the condition weight has increased by 10 gsm suddenly due to retention chemical variation.

Weight variation

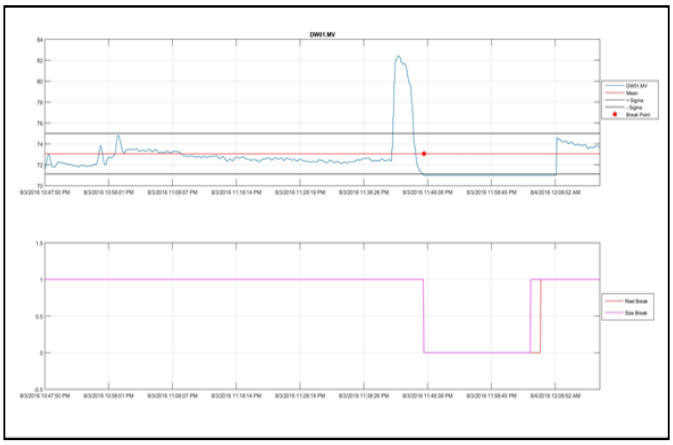

Figure 5 – Break detected due to weight variation

Ash variation

Figure 6 shows Sheet break due to large variation in Ash of about 2%.

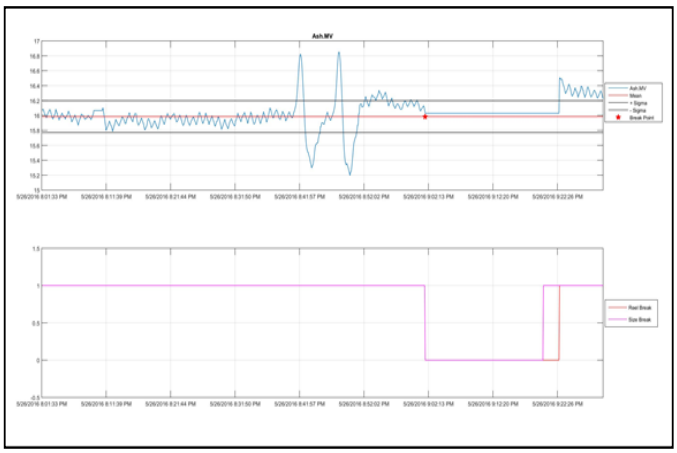

Figure 6 – Break detected due to Ash variation

Stock Approach Variation

Figure 7 shows that Sheet break occurred when the centricleaner reject tank level dropped suddenly.

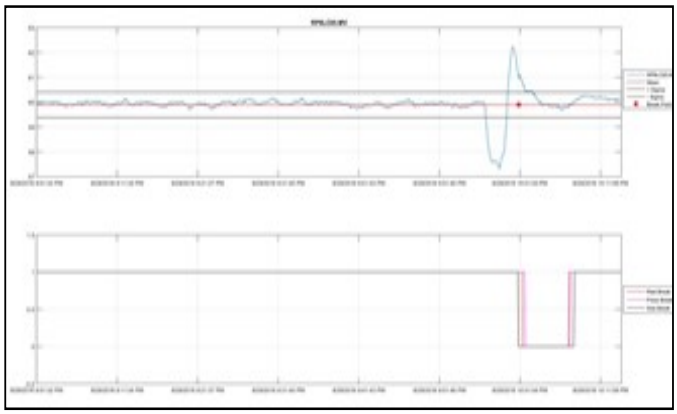

Figure 7 – Break detected due to Centricleaner variation

Chemical variation

Figure 8 shows that Sheet break has occurred when the bentonite chemical has varied significantly which was causing the sheet break.

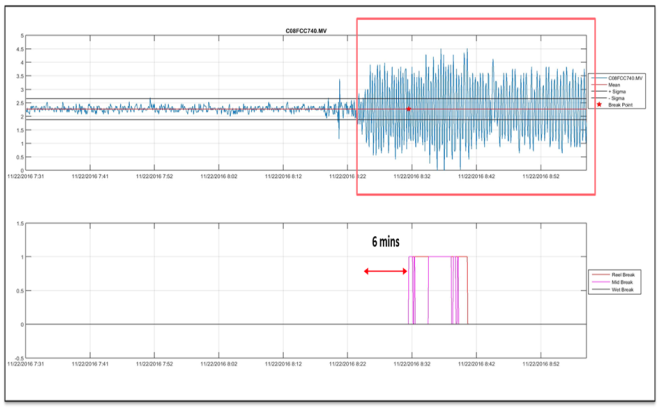

Figure 8 – Break detected due to Bentonite variation

PH variation

It was noticed that during chemical cleaning sequence the alum flow varied & pH increased drastically.

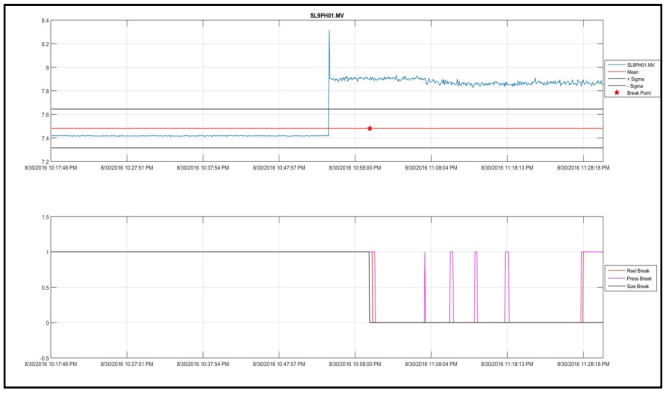

Figure 9 – Break detected due to pH variation

Figure 9 shows that Sheet break occurred when the stock pH increased suddenly and the chemical dosage experienced abrupt changes.

Vacuum variation

Figure 10 shows that Sheet break has occurred when the Couch vacuum has varied from -380 to – 345 mm hg. Draw variation has been observed after the break.

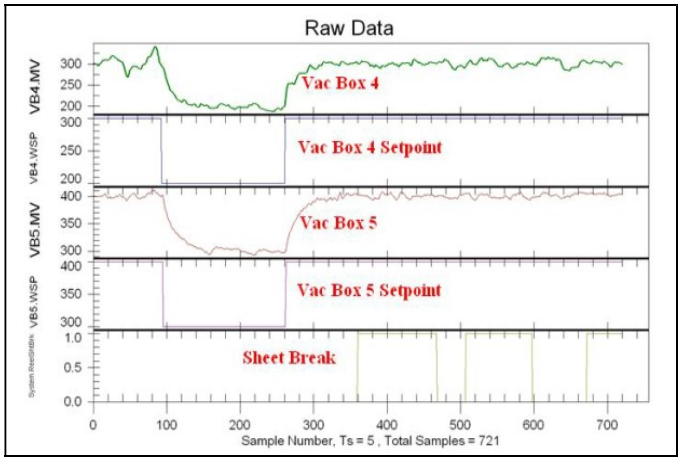

Figure10 – Break detected due to Couch vacuum variation

Machine Speed changes

Figure 11 shows the effect of machine speed on sheet break. It was noticed that there was sheet break during the speed increase. Further deep dive reveals that till 1450 the press and wire drainage seem good. But after 1450 mpm speed, the drainage rate has been drastic which created an issue with paper characteristic in pre dryer. This creates paper wrinkles, crease etc which cause the sheet break in any dryer section

Figure 11 –Break detected due to drainage

Grade Change variations

Figure 12 shows that sheet break occurred during grade change. During grade change (transition) without proper coordination and control, the entire process could have radical fluctuations and produce significant amounts of off-spec paper and even cause sheet break as shown above.

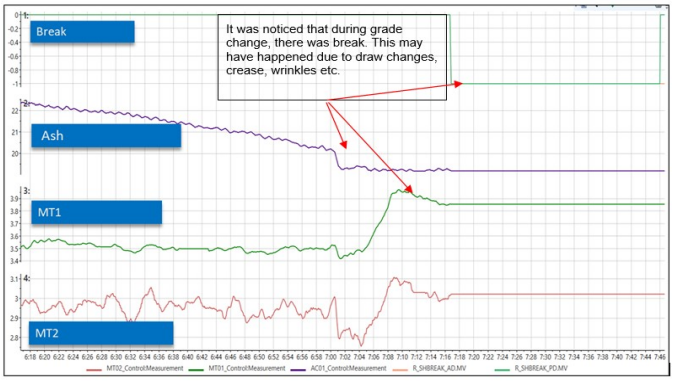

Figure 12 – Sheet Break detected due to Grade Change

Headbox Variations

Figure 13 shows that the break which resulted from weak points, insufficient ability to stretch relative to draw & air handling & 1st dryer fluttering issues.

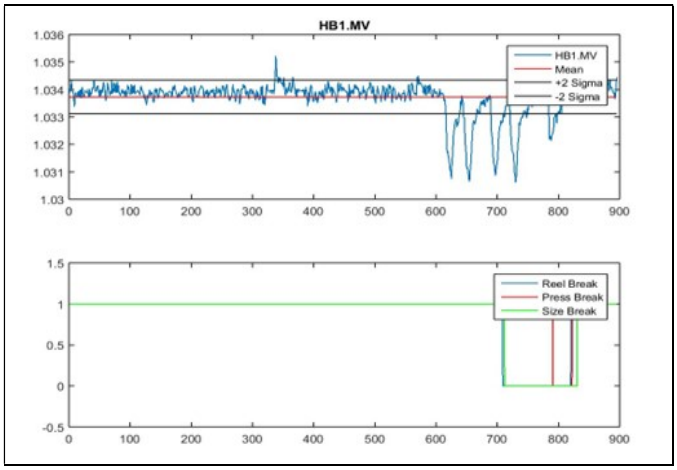

Figure 13 – Break detected due rush/drag variation

Steam Dryer variations

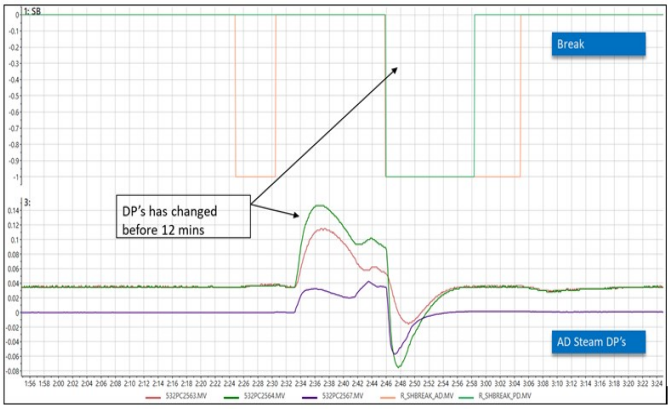

Figure 14 – Break detected due DP at 1st Dryer section

The ability of the paper web to stretch to some degree without breaking is expected to be a function of the paper's dryness. The above figure14 showing the variations at 1st dryer group DP which produce local over drying & caused paper break.

RECOMMENDATION

Once the causes for the Sheet breaks are identified, we followed the next step which was recommendation of the corrective actions to avoid the sheet breaks. These recommendations are a function of the analysis performed on the data collected as well as observations made during the Paper Machine Sheet Break work. The major issues for the instability of the Paper Machine were identified as

- Wet end variability, which was causing the product variability and also taking longer time to stabilize after sheet breaks. It was recommended to stabilize the wet end by improving loop tuning and reduce intermittent variations in the process.
- Chemical variability, which was causing product chemistry variations leading to sheet breaks. It was recommended to stabilize by tuning the chemical flow controllers, and better preparations at the back end.

- Vacuum variability, which was causing instability in retention, drainage etc. created fluctuation in the sheet draw, tension causing breaks. It was recommended to improve the vacuum system by tuning vacuum section related control loops.
- Headbox variability, which was causing instability in head box stock delivery causes sheet breaks. It was recommended to find out the source of Head Box CP dilution flow and DP variations.
- Steam and Condensate variability was causing instability in moisture variations resulting in sheet breaks.
- Since manual grade changes can lead to draw changes, crease and wrinkles leading to sheet breaks, it was recommended implement Auto Grade Change to prevent sheet breaks.

IMPLEMENTATION

Chemical Cleaning Sequence improvements

It was observed that the Basis weight, Moisture variation intermittently. Further process analysis revealed Cat Starch was observed to have sudden variations. It was observed that a line is taken for batch processing. Every time the batch processing valve is open a huge upset in Cat Starch to machine flow happens. With customer's effort, we have decoupled the effect of both lines which improved the chemical variations

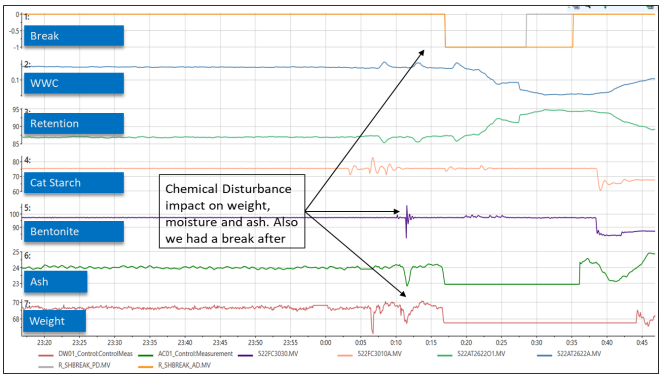

Figure 15 – Breaks due to Chemical upset

Silo Level Variation reduction

The level and variation of charge have a considerable effect on process status and operation. These can be considered with regard to three alternative situations: low charge, high charge, and varying charge. As the charge level is very much dependent on pH and thin stock consistency which is closely linked with process status & operation. Small correction in silo makes up system, Centricleaner settings, overflow improvement & tuning of the silo level improves the whole situation.

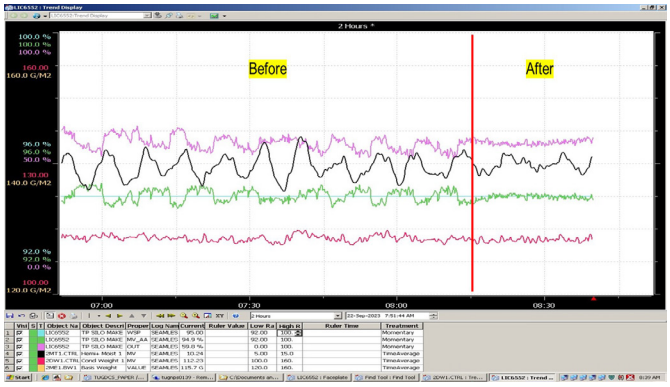

Figure 16 – Silo Level variation improvement

Vacuum Roll affects the runnability

The below figure17 shows the weight, moisture and ash variability (MDL, MDS, CD and TOT) was very high after changing the vacuum roll in press section which resulted in a greater number of breaks. After changing the roll, the break has come down drastically

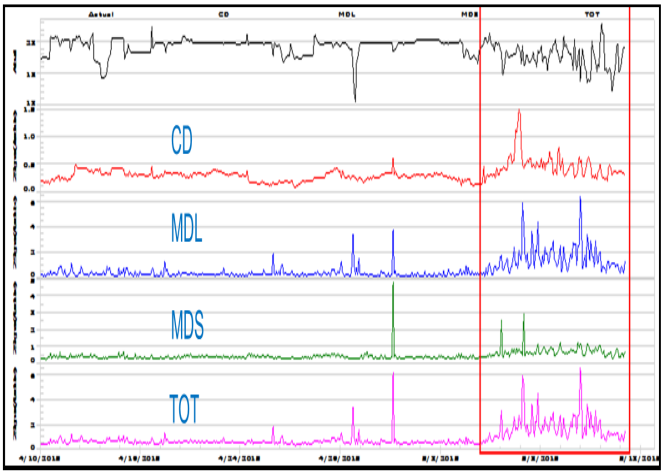

Figure 17: Vacuum roll increases the variability and resulted in breaks

Vacuum Tuning Improvement

Vacuum systems are essential for papermaking. They contribute to sheet formation and dewatering, press performance, felt conditioning, and general machine runnability. The vacuum system includes several sub-systems for vacuum control, air/water separation, and vacuum pump seal water management. The fine tuning of vacuum system reduced the sheet break recovery time which also contributing to reduction in sheet break time.

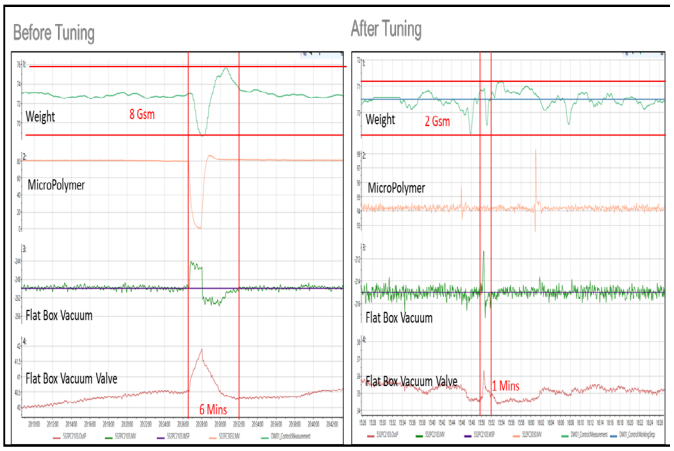

Figure 18: Vacuum Tuning improves sheet break recovery

RESULTS

The methodology describes in Section 2 was implemented successfully in several mills with attractive economic benefits. Figure 19 shows the improvements achieved in a Paper Machine of capacity 800 TPD producing writing and printing type of paper in South Asia. With the implementation of the integrated methodology for sheet break analysis and performance improvement, the average sheet break time has come down from 65 hours to 25 yours per year which was approximately 62% reduction. Monthly analysis of the data to see the how the sheet breaks are reduced after corrective actions.

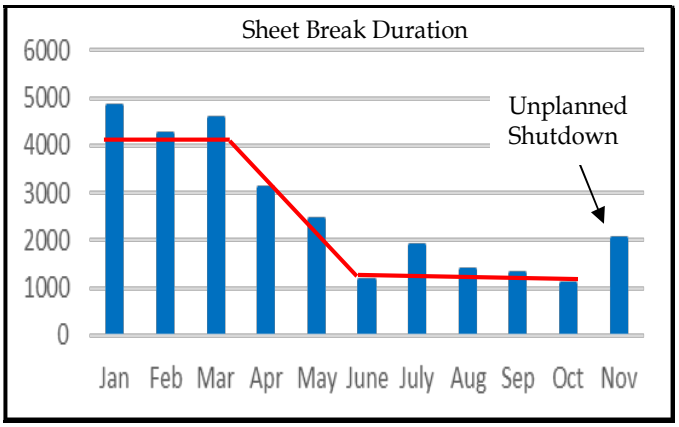

Figure 19 – 62% reduction in Sheet Break

CONCLUSION

An integrated advanced data analysis methodology was developed for diagnosing the causes of Sheet breaks in paper machines and successfully implemented in an operating paper machine. The major issues for the instability of the Paper Machine were identified as Wet end variability, which was causing the sheet breaks and also taking longer time to stabilize after sheet breaks. Implementing corrective actions in the Wet End resulted in significant improvement in level 1 loops and also Basis weight and moisture. This improvement in Stock preparation and Steam & Condensate area resulted in reduced the sheet breaks and faster basis weight control reduced the off grade after the sheet break.

The reduction in sheet breaks has resulted in an estimated annual savings of $466,000. The implementation of the recommendations has resulted in:

- Increased production
- Improved sheet quality
- Reduced sheet breaks
- Reduced grade change times.
- Faster sheet break recovery times

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