Application of Data Analytics Tools for Increasing Liquor Productivity in Alumina Refinery

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Abstract

Data analytics has emerged as a major technology enabler for the manufacturing industry to achieve operational excellence. Digitalization is an important pillar in the strategy deployment of refineries with the emergence of the concepts on Internet of Things, Robotics, Digital Twins and Block chain helping organizations accelerate their performance with higher customer engagement and lower operating costs.

Although, cost competitiveness was a major driver for the alumina refineries earlier also, this has gained a major focus with the stringent regulations on the decarbonization and net carbon input. Improvement in liquor productivity has a major impact on operations leading to substantial savings in power consumption, and reduction in net carbon.

Improvement in liquor productivity involves optimizing the hydrate precipitation process, as well as strengthening the precipitation growth & cooling circuit, which are very capital intensive. However, application of data analytics concepts can help in identifying the optimized conditions for increasing liquor productivity, without going into major technological upgradations.

In this present development work, process data from the precipitation section was analysed using data analytics tools to arrive at an optimum condition for increasing liquor productivity. Systematic process was put into place involving the following major steps viz.

1. Data Review & Classification
2. Data Cleaning
3. Capability & Normalization and
4. Predictive Analysis

The predictive model developed for liquor productivity was deployed for arriving at operating conditions & implementing by process tweaking to achieve the desired process conditions. This led to an increase in liquor productivity from ~ 73 g/L to ~ 78 g/L consistently. Increase in liquor productivity led to substantial savings in steam consumption for the refinery.

This paper presents a detailed process of model development, its application, and the benefits in terms of operational excellence for the alumina refinery.

Keywords: Alumina refinery, Bayer process, Data analytics

1. Introduction

Alumina Industry, at present, is at the cusp of embracing digitalization as an enabler for achieving operational excellence for the refinery. Refineries are undergoing digital transformation on operation and maintenance, changing from manual and paper-based tasks to new ways of working based on digital automation and software. Alumina refineries are deploying digital operational infrastructure, with wireless sensors, purpose-built data analytics, industrially hardened tablet computers for digital document and software forms, location awareness for personnel and assets, and connected devices using cloud computing technology and Industrial Internet of Things (IIoT) in order to enable these new ways of working, [1].

Application of data analytics for process improvement in alumina refineries has gained a major importance in the recent years with the emergence of digital twins, with predictive and prescriptive models especially for digestion and calcination areas of the refinery, leading to substantial savings in specific energy consumption as well as the total net carbon input. Successful application of data analytics in digital twin for predicting the air flow & mass flowrate in a calciner has been successfully demonstrated, leading to ~ 25 % reduction in fuel consumption and consistent product quality. In addition to the digital twin development, which requires mapping of the measurement points and deployment of soft sensors for its implementation, data analytics tools can also be used to arrive at a set of optimized process conditions through predictive models. One such important application of predictive analytics is for estimating the conditions for increasing the liquor productivity in alumina refinery. Using these analytics as a tool, historical process data on precipitation area can be analysed and a predictive model can be built in understanding the optimized conditions for increasing the liquor productivity in the refinery without going into major technological upgradations which are highly capital intensive.

Here, an attempt has been made in developing a robust model for predicting the liquor productivity using a set of optimized conditions as an input. Hence, based on the outcome of this model, a set of process conditions are implemented in the refinery with minor tweaking of the process, leading to an increase in the liquor productivity from 73 g/L to 78 g/L on a consistent basis. Increase in liquor productivity led to substantial savings especially in the steam consumption.

This paper presents a detailed process of model development, its application, and the benefits in terms of operational excellence for the alumina refinery.

2. Conceptual Approach

Liquor productivity in alumina refinery is dependent on the following parameters viz.

1. Caustic concentration of the LTP [2]
   a. Higher the caustic concentration of the liquor, higher will be the alumina holding capacity of the liquor under given conditions of temperature.
   b. Higher caustic, however, has a negative impact on the soda content in hydrate.

2. Alumina / Caustic ratio (A/C) of the LTP
   a. Operating at a higher A/C of LTP (albeit depending on the solubility conditions of liquor), increases the driving force for precipitation thereby increasing the liquor productivity
   b. Operating at a higher A/C also increases the supersaturation at start of precipitation and increases the rate of precipitation.

3. Temperature gradient from the agglomeration start to growth of precipitation end
   a. Increase in the temperature gradient coupled with the concentration and ratio profile across the agglomeration and growth circuit, increases the supersaturation thereby increasing the liquor productivity.

4 Seed charge (fine and coarse) of hydrate per tonne of liquor to precipitation
   a. Increase in seed loading (surface area per unit mass) increases the liquor productivity.

It is important to understand the interrelationship between these parameters and its impact on the product quality to arrive at the optimum conditions. Hence an attempt has been made to use data analytics for scanning the process data in order to establish the interdependency and verifying it with the scientific knowhow and finally arrive at a predictive model for a set of process conditions as input.

3. Development of Model for Liquor Productivity Improvement

The conceptual approach followed for model development is explained in Figure 1.

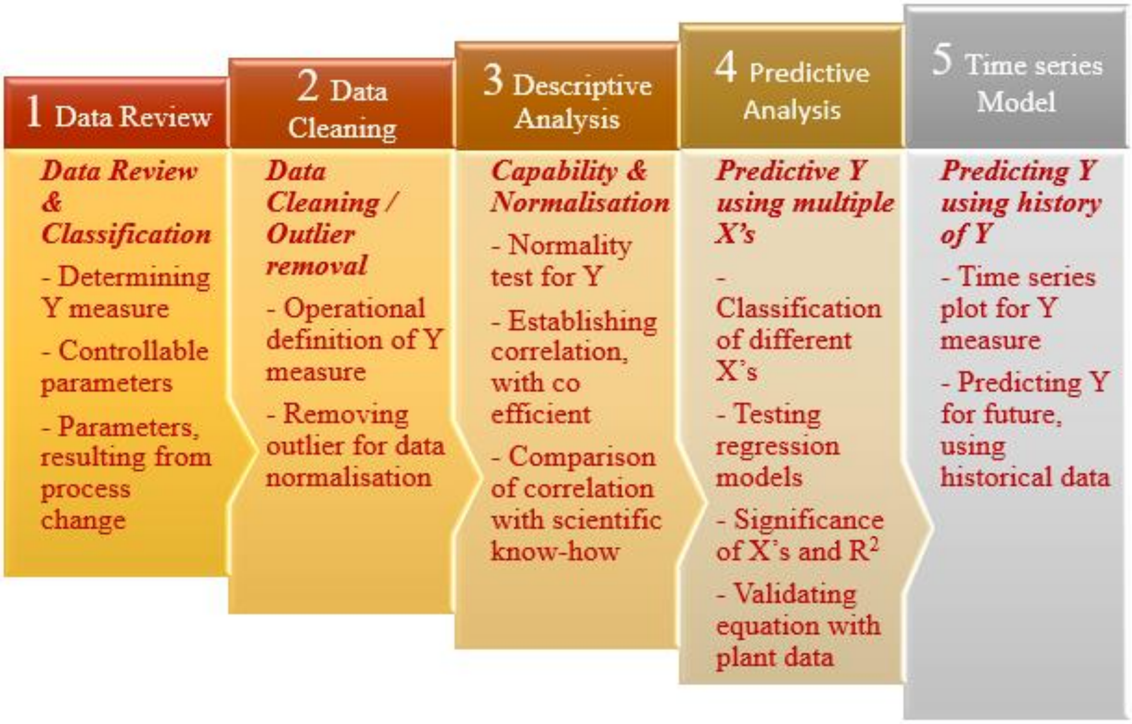


Figure 1. Conceptual approach for model development.

The model development consisted of the following 5 steps, as below.

1. Data Review:

- Raw process data pertaining to the precipitation area of the refinery was first analysed to determine the Y measure, mainly the liquor productivity
- Data was classified into two buckets, namely controllable parameters and parameters resulting from process change. This classification helped in arriving at the major controllable parameters.

2. Data Cleaning:

- Operational definition of the Y measure (liquor productivity) was done, which included the formula for the estimation, as well as the measurement of the individual inputs.
- The overall data was checked for outliers. The outliers were analysed for their origin and frequency and then removed from the data.

3. Descriptive Analysis:

- Data was tested for normality and scatter plots were done for understanding the relationship between the variables and relationship was compared with scientific know-how.

The scatter plots from the descriptive analysis are presented in Figure 2.

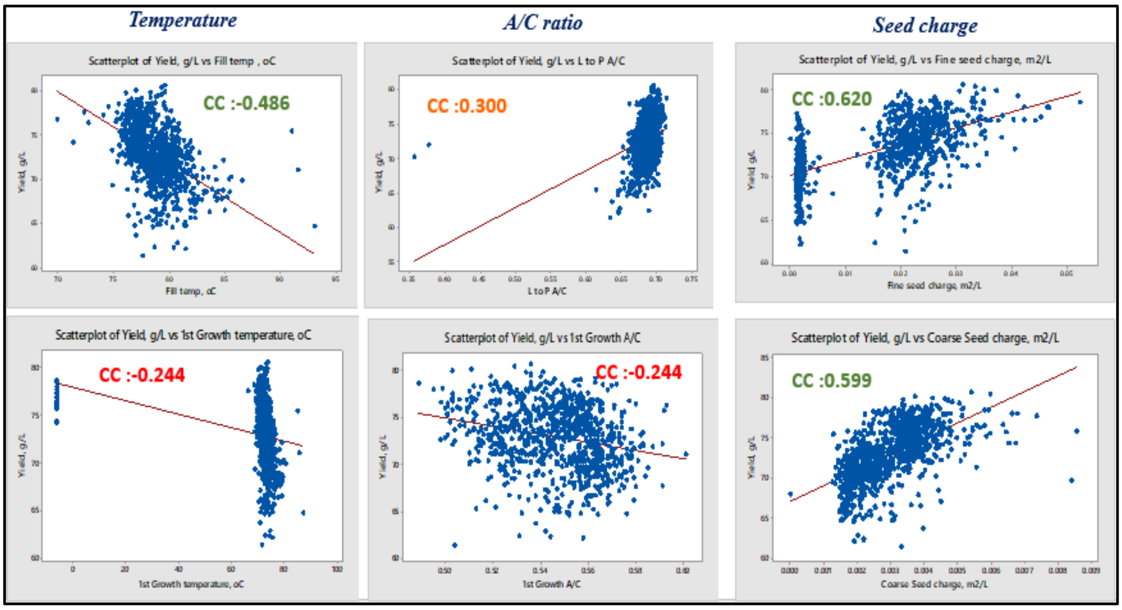


Figure 2. Descriptive analyses.

From the above figure, the following observations can be made:

- Correlation coefficient for temperature and seed charge are higher than that for A/C
- There is a wide variation in the liquor A/C values which are affecting the correlation coefficient
- There is a clear trend of increase in liquor productivity with the decrease in temperature and increase in coarse and fine seed loading.

4. Predictive Analysis:

- After the descriptive analysis was completed and initial relationships were established with the parameters, a model was then built for predicting the liquor productivity.
- Classification of the different X's (dependent variables) was done, and various regressions models were run.
- Model with the highest predicted R^2 was selected for the final validation with refinery data.

The model results and the validation are given in Figure 3 & 4 respectively.

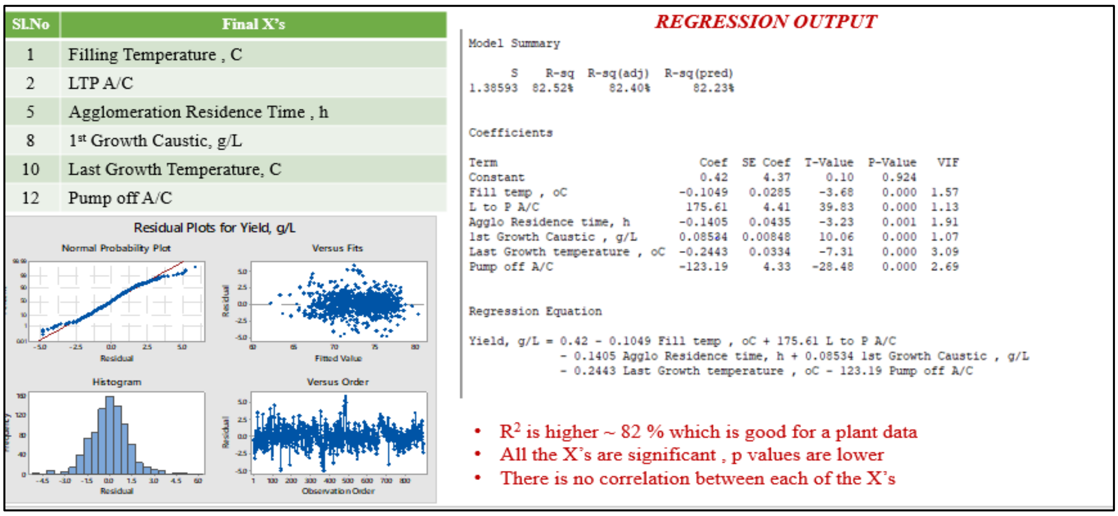


Figure 3. Predictive model for liquor productivity.

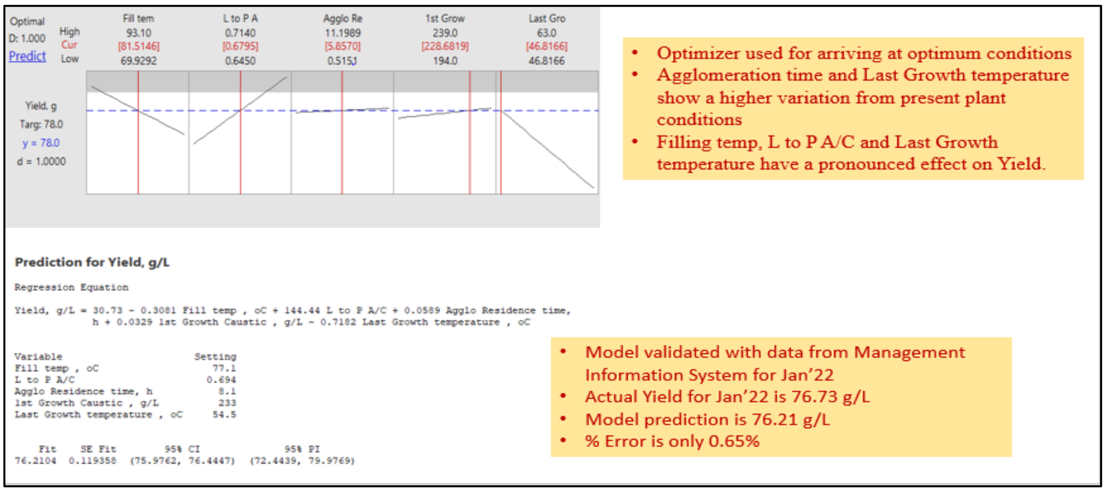


Figure 4. Model validation.

5. Time Series Model:

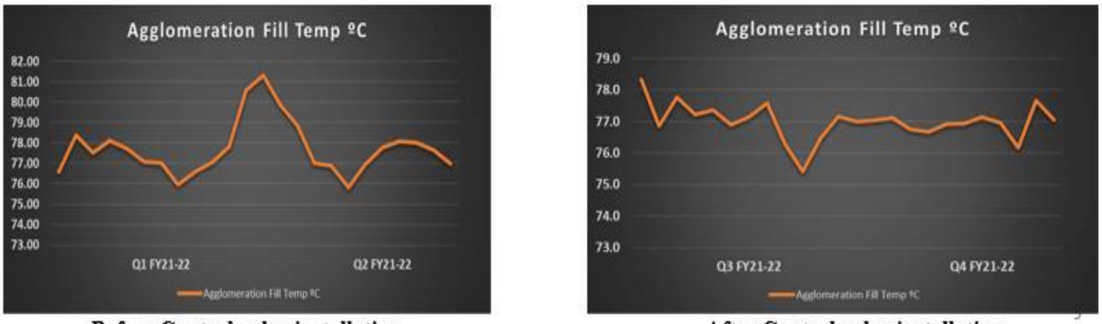
- Time series plot was done for the data on liquor productivity to understand any trend or seasonality in the data.

4. Model Application in the Refinery

Based on the results of the model and the validation with refinery data (with minimal error of only 0.65%), work was done for implementing the optimized conditions resulting from the model in the refinery. The implementation process consisted of the following steps:

A. Improvement in Agglomeration Filling Temperature:

With the use of control valve to adjust flow of pregnant liquor bypass, instead of manual valve operation, the agglomeration filling temperature was fine-tuned, resulting in better control over temperature profile for maximizing productivity as per the model. The agglomeration filling temperature profile, before and after modification is given in Figure 5.



Before Control valve installation **After Control valve installation**

Figure 5. Agglomeration filling temperature profile.

I. Optimization of Agglomeration Conditions:

Agglomeration residence time was optimized through controlled seed charge of both fine and coarse seed hydrate. The specific surface area (SSA) of fine seed particles was increased through optimum Apex size selection of hydrocyclones spigot, resulting in better agglomeration and achieving the target supersaturation to seed ratio and agglomeration efficiency.

II. Optimization of Growth Conditions:

Interstage cooler relocation was done from 3rd stage of New Growth to 1st stage of New Growth leading to higher supersaturation of alumina and thereby increasing the mid precipitator slurry solids.

III. Optimization of Total Precipitation Residence Time:

Through efficient planning and scheduling, availability of tanks was ensured which helped in maintaining the precipitation volume constant. This resulted in an increase in the residence time from 40-41 h to 43-44 h, thereby resulting in an increase in the hydrate precipitation per unit volume of liquor.

4.1 Benefits of the Model

With the application of the inferences from the model and its implementation in the refinery as highlighted above, there was an increase in the liquor productivity to 78 g/L. The increase in the liquor productivity to 78 g/L led to substantial savings in the steam and energy consumption for the refinery. The increase in the liquor productivity and the benefits are presented in Figure 6 & 7 respectively [3].

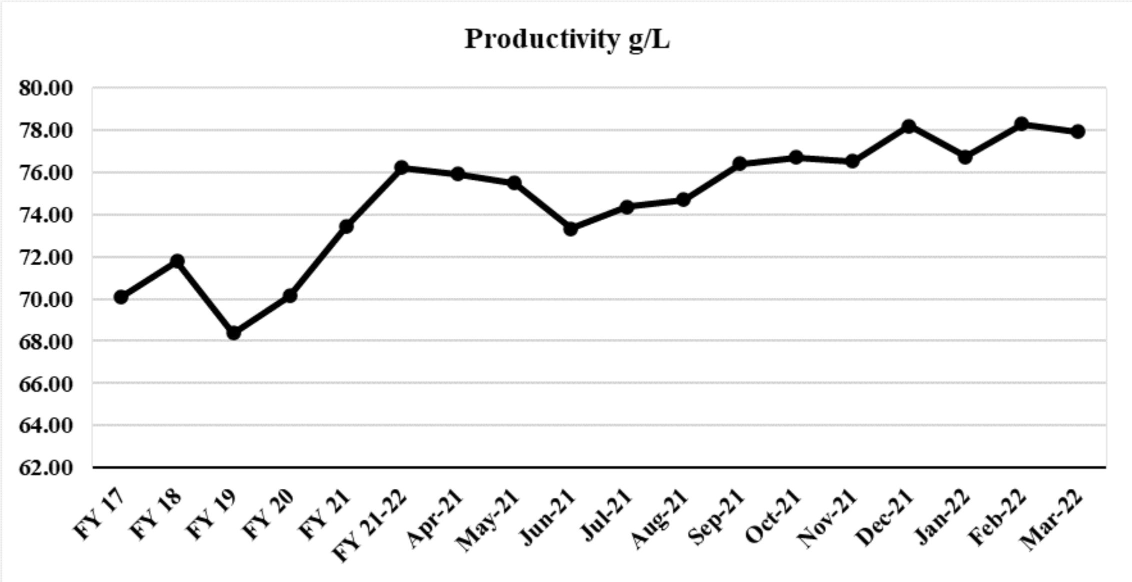


Figure 6. Liquor productivity increase.

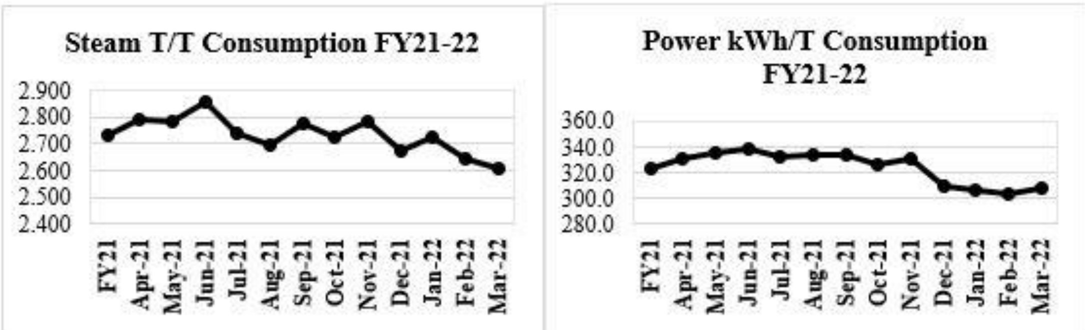


Figure 7. Reduction in steam and power consumption.

5. Discussion

This development discusses about using data analytics as an enabler for achieving operational excellence for the refinery. Using data analytics, the historical process data, pertaining to the precipitation area of the refinery was analysed in a systematic manner involving the following major steps viz.

1. Data Review & Classification
2. Data Cleaning
3. Capability & Normalization
4. Predictive Analysis
5. Time Series Model

These steps were used for arriving at the Y measure from the data, treatment of outliers and normality testing of data, descriptive analysis of the data for arriving at statistical inferences and comparison with scientific know-how and finally, development of an analytical model for predicting the liquor productivity based on the optimized dependent (input) variables. The model obtained was validated with refinery data and it showed an error of only 0.65 %. Further this model was suitably implemented in the refinery by suitably tweaking the process, especially the agglomeration & growth conditions and total residence time in the precipitation area, thereby resulting in an increase in the liquor productivity to 78 g/L consistently. This increase in liquor productivity resulted in substantial savings in steam and power consumption for the refinery.

6. References

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