Batch Digester Optimisation and Control System- An Indigenous Approach

Prasad Gandikota, B. Sundaresan, S. Uma, S. Chandrasekar and P. Sudhakara Rao

Central Electronics Engineering Research Institute-Chennai Centre, CSIR Madras Complex, Taramani, Channai-600113

ABSTRACT

Over the last two decades, the ability to manage digester house has significantly improved with the usage of digital control systems. Like in other areas, the new sensor and electronic & digital control systems are playing major role to automate the operations in the pulp mill area too. These highly powerful & versatile electronic devices with appropriate firmware are not only acting as control systems but also contributing towards the batch digester optimization. Batch digester control has found renewed interest in the industry for two reasons: firstly, for any mill to produce quality paper should produce quality pulp with minimum costs. Secondly, it is relatively easy to modify existing installations. CEERI, in its continuous efforts of developing indigenous technologies for pulp and paper industry, has recently developed a batch digester control system with the support and funding of Ministry of Communications & Information Technology (MoCIT) with the following objectives of provide uniform pulp, producing higher yields, reducing steam usage per ton of pulp, improving degas/relief valve control and uniform charging by controlling the operations of cooking cycle of each batch using a Digital Control System (DCS). This paper describes the capabilities and features of the developed system.

INTRODUCTION

In any paper mill, the batch digester operations involve measurement of the weight and moisture content of the chips during the chip charge. White and black liquor volumes charges are based on the alkali/wood and liquor/wood ratios using white and black liquor strengths values and sulfidity. It is therefore necessary to measure these variables accurately to avoid a large cumulative error. Similarly, during the cook phase, three factors namely, cooking time, cooking temperature and concentration of the effective alkali during the cook will influence the delignification in the chips. Finally, during the blow phase, blow operation is initiated after attaining the target H-factor. Digester batch control involves monitoring and control of the various process parameters in each of these phases of the cooking cycle. Since these are batch operations, the cooking cycle operations are to be automated in order to avoid batch-to-batch variations. The following sections will describe the instrumentation requirements and automation features implemented in the system.

RESULTS AND DISCUSSION

Digester charging

Chip and liquor filling are the two operations of digester charging.

Chip filling

The chips from the silos are transported on series of conveyors (the number of conveyors depends on the mill). The chips thus transported drop on the shuttle conveyor, which can be positioned to the selected digester for charging. The instrumentation requirements to monitor and automate chip charge operation is given in Fig. 1.

The system will monitor the charging sequence and integrate weighto-meter reading to charge the required quantity of wood chips. Chip moisture can be from an online moisture sensor or can be entered manually to calculate Bone Dry (BD) weight.

i. Electronic Belt Weighing System (Conveyor system) to measure the weight of the chips.

ii. Moisture meter to calculate bone dry weight.

Fig 1: Instrumentation for chip filling

This value helps to calculate the liquor charge parameters automatically. Identification of the shuttle conveyor position and placing the same at the selected digester can be automatically done.

Necessary interlocking system is built in for starting and stopping the battery of conveyors. Once initiated, the

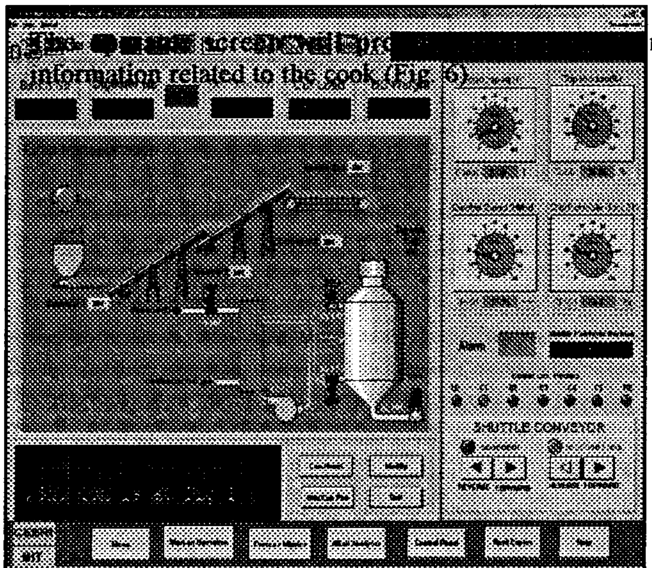

Fig 2: MMI of chip filling

system checks whether the selected digester is ready for charge or not and initiates charge only when it is ready. The chip charge sequence is completely animated for the operator's convenience. (Fig. 2)

Liquor filling

The volumes of liquor to be charged, both white and black liquor, is determined based on the target alkali/wood ratio and target liquor /wood ratio. Liquor filling is fully automatic or it can be initiated by operator's command for liquor fill for each digester. The liquor fill instrumentation requirements are shown in Fig.3

i. Lelvel Transmitters to measure the level of black liquor and white liquor tank.

ii. Magnetic flow transmitters to measure the flow of black liquor and white liquor.

iii. ON/OFF Solenoid valves to add the set quantity of black liquor/white liquor into the digesters.

Fig.3: Instrumentation requirements for liquor fill

Once initiated, the system will do a series of checks before starting the liquor charge. These checks ensure whether digester selected for liquor charge is ready for liquor fill and type of fill (white liquor or black liquor) and whether required volumes of white and black liquor are available in the respective tanks.

After, the chip and white liquor charge, the black liquor charge will be done. Operator will be notified after liquor fill sequence is completed.

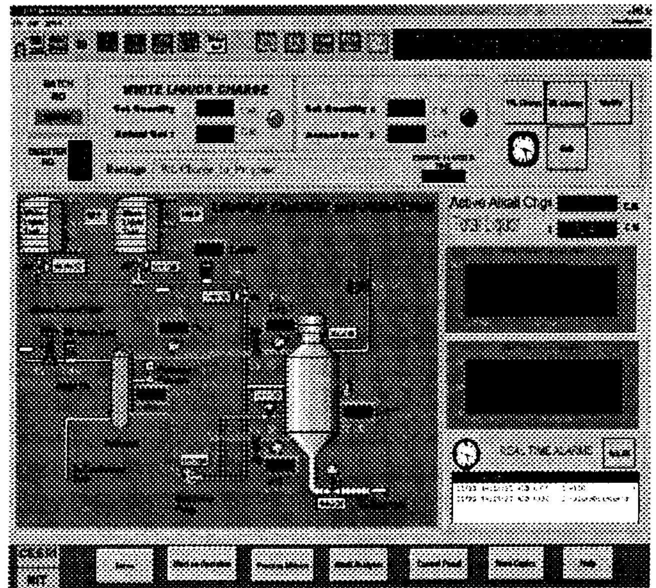

Fig. 4 MMI of Liquor Fill

The operator screen will provide all the necessary information related to the liquor charge (Fig.4)

Digester cook

The operating parameters such as grade targets, pressure, time to temperature and time at temperature, maximum temperature are entered along with the batch number at the time of initiating a new batch. These values are recalled and used for digester cook control.

After the liquor and chip fill sequences are completed and when the cook command is given, the system will ensure that digester cap, blow valve and liquor valve are closed. Then cooking cycle automatically starts. The cooking can be a single phase cooking or two phases cooking depending on the operating conditions of the mill. Operator can select either of them.

The instrumentation requirements for complete control of a cooking cycle is given in Fig. 5

During the cook, the operator can have the display of the process parameters like temperature, pressure, H-factor value continuously and effective alkali concentration at regular intervals. Cooking temperature is maintained so that the target H-factor is reached at scheduled blow time.

i. Temperature Transmitters
ii. Pressure Transmitters
iii. Steam control valve
iv. Control valve for degassing.
v. Online Effective Alkali Analyzer to measure the concentration of cooking liquor.

Fig. 5: Instrumentation require-ments for cooking cycle control

The operator screen will provide all the necessary information related to the cook (Fig. 6)

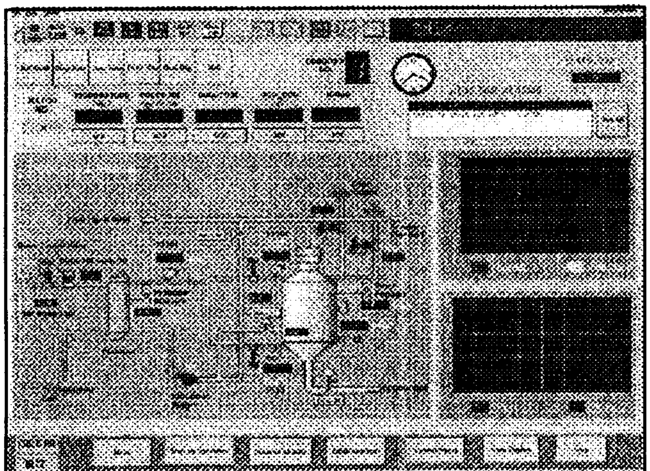

Fig. 6. MMI of Cook

Excess pressure monitoring and relief control

At the start of the steaming, the relief valve will be opened at a predetermined value. After attaining certain pressure in the digester, the computer system will control over pressure in the digester by means of relief valve control. This over pressure is calculated as the difference between the dome pressure and computed pressure based on the vapor pressure of the cooking liquor.

Online effective alkali analyzer

Effective alkali concentration measurement is used for two important reasons:

a. To use in the feedback loop to control AA charge such as to maintain a target average EA in each cook.

b. To use in a feed forward loop to control cooking temperature so that the target K-Number is reached at blow time.

Online effective alkali analyzer has been developed to monitor EA concentration of the cooking liquor during the cooking process. This analyzer will take sample of the cooking liquor at regular intervals or as programmed by the operator, from the liquor circulation line.

The principle of operation is very simple. It is based on volumetric titration between a strong alkali and weak acid. The weak acid used here is carbon-di-oxide. The reaction is exothermic.

A known volume of cooking liquor (alkali) with carbon-di-oxide at a fixed flow rate is titrated in a cell. Due to the exothermic reaction, the cell temperature keeps increasing. After certain time the temperature starts falling down. The point during titration at which effective alkali exhausted is identified by precisely measuring the maximum temperature. The effective alkali sensor program uses the measurement of the mass of carbon-di-oxide required to reach this point to calculate effective alkali concentration.

The online EA analyzer developed is shown in Fig. 7

This analyzer measures EA concentration from 5 g/l to 70 g/l, which is, expressed in g/l as NaOH of wood or g/l as Na2O of wood.

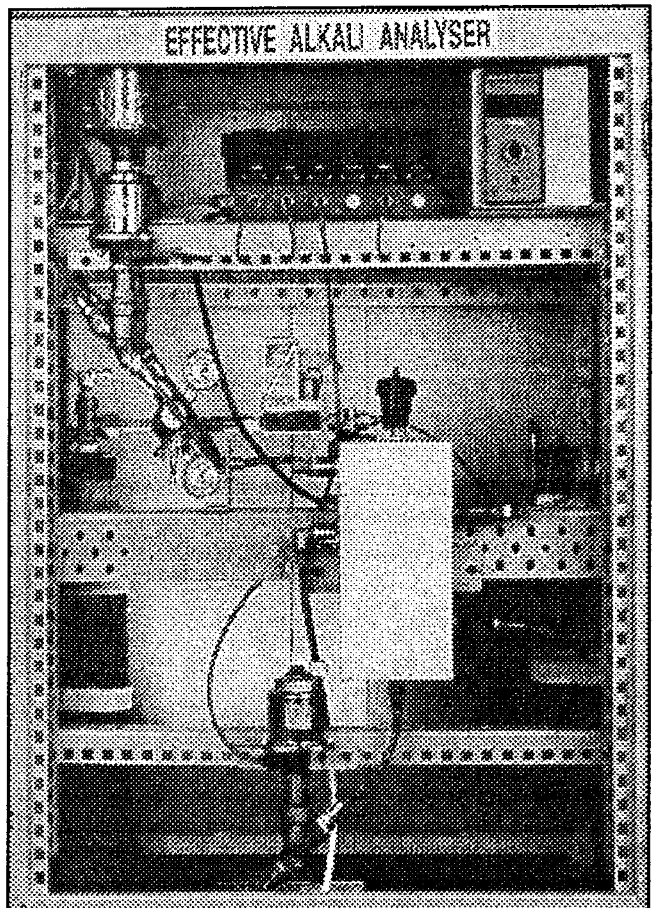

Fig. 7 EA analyzer

Some typical values of the laboratory experiments carried out with alkali of 10gm/lt concentration are shown in Table 1.

Table 1. EA Analyzer experimental results

Analyzer values in (g/l)	Error
9.56	- 0.46
10.69	0.69
9.88	- 0.22
10.20	0.20
10.75	0.75
The values obtained are within +/- 1.5 g/l accuracy.	

Blow operation

When the cook reaches the target H-Factor based on the grade or cooking model, digester will be ready for blow. This will be informed to the operator so that he can initiate the blow operation.

The operator can initiate blow control. Before blowing, the system check the level of the blow tank selected and initiates blow only if the level is below a predetermined value. The system will also performs a number of safety checks to be sure that it is a permissible blow.

Batch digester optimization stratiegies

For any mill, there are four basic requirements to successfully implement batch digester optimization strategies:

1. To obtain an accurate, precise indication of process temperature.
2. To obtain a reliable liquor sample from the digester.
3. Accurately and precisely measure the effective alkali concentration.

Processing the above information in the process model quickly.

The developed system will provide all these basic requirements for optimization. Further, there are several models found in the literature, which can be adopted for model based control strategies.

System hardware, software & human machine interface

The system is developed around well-proven and tested DCS hardware. The system has necessary analog and digital channels to control the cooking cycle of 5 batch digesters. The developed system is shown in Fig.8

The entire system software is modular and mill independent. All the necessary interlocking features are built in the system. System also identifies some of the most common human errors and indicates to the operator accordingly.

Software is user friendly and thé operator will be informed about the current operation going on in a digester and indicate what he should do after completion of the current operation.

Process parameters display, trends and graphs of all the important parameters are displayed.

When implementing a control configuration, the human interactions with the control system by the operator are implemented. These are input set points, initiating a particular operation, system configuration, etc.

Benefits expected

It is very difficult to quantify the benefits based on the lab trials and more authentic figures could be arrived only after the field trials of the system.

Fig. 8: Digester Control System

CONCLUSION

The following benefits are expected after it is being implemented in a plant:

- Cut in the Kappa Number standard deviation at least by half
- Increase in the pulp yield by 1%
- Significant reduction in the steam usage per every ton of pulp produced
- Reduce steam swings and smooth steam demands

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