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Model Based Temperature Control of Lime Kiln Process

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Abstract

The limekiln process is multi-variable process with long time delays. Kiln control in the recovery section is very important for efficient production. The absence of closed loop controls results in inefficiencies in fuel consumption and variation in reburned lime quality. The goals of limekiln automation includes improved lime quality, increased production, improved fuel efficiency, increased refractory life, improved kiln information gathering and processing.

Difficulties in limekiln operation using PID controller includes that it is multivariable process with strong interactions between variables, presence of long transport delays and long response time, changing operating conditions and frequent disturbances.

Model predictive control (MPC) strategy is an indispensable tool for designing controllers for a multivariable complex, delayed and constrained industrial process. The operational objective of a kiln is to produce good quality lime. Secondary objectives include minimization of the energy utilization and maintaining the front end and back end temperature i.e. temperature of the hot lime within specified bounds. By controlling fuel flow rate at the front end and id fan opening % at back end of kiln the temperature at both ends will be controlled.

Keywords:

Lime Kiln; MATLAB; Model predictive controller; PID controller

1. INTRODUCTION

A rotary kiln process is a strongly coupled, multivariable, and nonlinear system with large lag. There are three types of lime kiln used in industries for batch and continuous operations. These are vertical shaft kiln, rotary lime kiln and fluidized bed lime kiln. Out of these majority of paper industries globally use rotary lime kiln. A rotary lime kiln is basically a large cylindrical tube tilted typically between 1.5 and 3.5°.

Kiln control in the recovery section is very important for efficient production. The absence of closed loop controls results in inefficiencies in fuel consumption and variation in reburned lime quality. Lime mud and lime sludge is given as the input and heated up to 1300°C. It consists of three sections Drying section, Heating section, Calcination, Cooling section.

Lime mud and sludge is given at the back end of kiln and fuel flow and air is given at the front end of the kiln to heat the lime. Id fan is used to remove the co inside the kiln. Air inlet is used reduce the co content which is send outside. Control of front end and back end temperature of kiln process is done by model predictive controller. In the existing method PID controller has many drawbacks like large settling time, time delays , high parameter values, inverse response. To overcome the drawback in PID controller MPC is used.

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Model predictive control (MPC) strategy is an indispensable tool for designing controllers for a multivariable complex, delayed and constrained industrial process. The complex dynamics and constraints make this process, an ideal choice for the application of MPC strategy. In the proposed method model predictive controller has many advantages like low settling time, reduce time delays. Model predictive control system provides overall balanced and optimized control of kiln process.

2. RELATED WORK

Out of these majority of paper industries globally use rotary lime kiln. A rotary lime kiln is basically a large cylindrical tube tilted typically between 1.5 and 3.5º. It is rotated at 0.83-0.85 rpm. Lime kiln average size is more than 100 meters long by 3 meters diameter with a production capacity of 400 metric tons/day of calcined product.

The measured outputs are the front end temperature and the back end temperature. The manipulated variables are the fuel flow rate and the damper percentage opening for air flow rate.

- Lime mud and lime sludge is given as the input and heated upto 1300°C. calcium carbonate is converted to calcium oxide(lime) and excess oxygen inside the kiln is removed out with the help of induced fan.

$CaCO_3$ (s) —> CaO(s) + CO_2 (g)   (1)

3.BLOCK DIAGRAM

The process flow diagram of kiln process is shown below in fig 1. It consists of manipulated variables and controlled varibles.

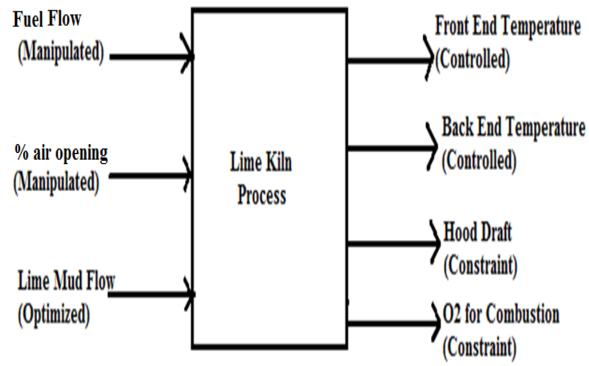

Fig1: Block Diagram of Kiln Process

The front end and back end temperature of kiln process is controlled by model predictive controller (MPC). By using MPC large time delays, multivariable constraints, response time can be improved.

4. KILN PROCESS

Lime kiln consists of a mud filter where the moisture content is reduced to about 30 to 35%, a rotary kiln and dust collector. The kiln itself is generally thought to consist of three sections. A typical kiln is shown below in Figure 2.

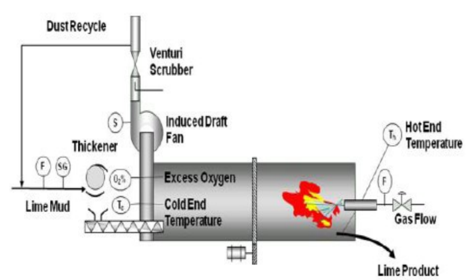

Fig 2: Typical lime kiln process

The first section is a preheater or chain section where the calcium carbonate mud is dried and nodulized. The second section is heating zone where lime mud is heated. The third section is a calcining zone where the feed is heated to about 1150°C and converted to calcium oxide. Some kilns have a fourth section where the quick

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lime is cooled and the secondary combustion air is preheated.

- Drying section – 200°C - 400 °C
- Heating section – 400°C - 600°C
- Calcination – 600°C - 1200°C
- Cooling section – 200°C

By using the system identification tool box in MATLAB, the final transfer function is

$$\begin{bmatrix} T_f(S) \\ T_b(S) \end{bmatrix} = \begin{bmatrix} \frac{1.66}{39S+1} & \frac{1.71}{4.4S+1} \\ \frac{0.34}{8.9S+1} & \frac{1.4}{3.8S+1} \end{bmatrix} \begin{bmatrix} U_1(S) \\ U_2(S) \end{bmatrix}$$

4.1 EXISTING METHOD

A. PID controller

In the existing method using PID controller the response has large peak overshoot, large settling time and high rise time.

The values are obtained from Ziegler Nichols method. The response of front end and back end temperature control of kiln process using PID controller is shown below in fig 3 & 4.

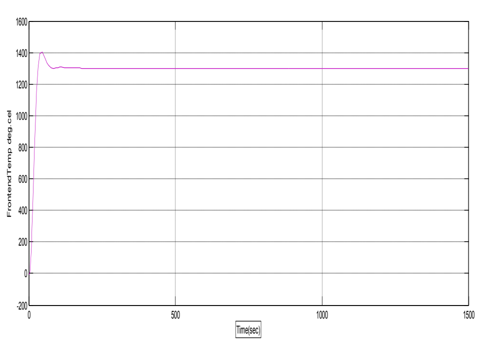

Fig 3: Front end temperature response using PID

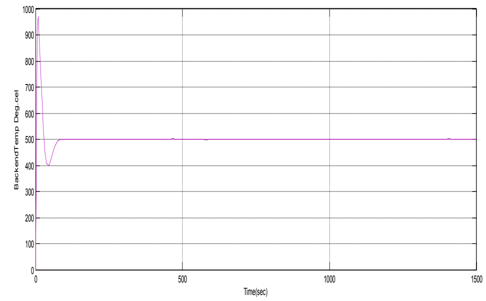

Fig 4: Back end temperature response using PID

B. MODELPREDICTIVE CONTROLLER

MPC is preferred for the following reasons. Processes are difficult to control with standard PID algorithm (eg : large time constants, substantial time delays, inverse response).There are significant process interactions between u and y i.e., more than one manipulated variable has a significant effect on an important process variable.

Constraints (limits) on process variables and manipulated variables are important for normal control. The advantage of using MPC is Reduced process variability, Improved in product quality stability, Increased production throughput, Less response time.

The response of MPC to control the front end and back end temperature is shown below in the fig 5.

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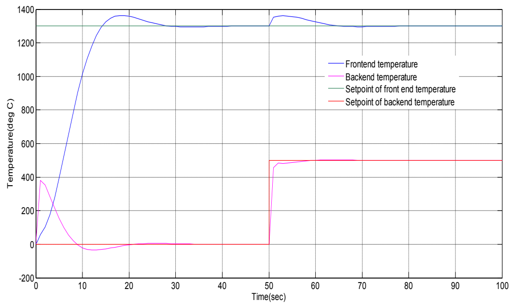

Fig 5: Response of temperature control of MPC

5. RESULTS AND CONCLUSION

5.1 Performance comparison between PID and MPC

From the tabular column below in fig 6.4 by comparing the performance of PID and MPC, MPC has low rise time, peak overshoot and low settling time.

Thus the temperature at front end and back end of the kiln is controlled by MPC has many advantages compared with PID controller.MPC is used for multi variable process. The settling time compared with the PID controller MPC has high.

PARAMETERS	PID		MPC	
	FRONTEND	BACK END	FRONTEND	BACK END
SETTLING TIME(SEC)	150	130	28	8
PEAK OVERSHOOT (%)	0.0769	0.94	0.0538	0
RISE TIME (SEC)	50	2	11	2

Fig 6: Performance comparison between PID and MPC

5.2 CONCLUSION

By controlling the fuel flow (i.e. front end or firing) and id fan opening % (i.e. feed or backend) the temperature of front end and back end is controlled using MPC. Thus MPC has faster settling time and less oscillation compared with PID response.

When applying this proposed method MPC has advantages like low settling time, reduce time delays. Model predictive control system provides overall balanced and optimized control of kiln process. In future this method will be implemented in the real time to get high accuracy at the output. Also this can be implemented using EMRAC, IMC.

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