# Development of Fuzzy Logic Controller Based Temperature Control for Kiln Control

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***Abstract- This research work is basically on Cement Kiln Temperature based on Fuzzy Logic Controller action. It is aimed at controlling temperature in a cement kiln using Fuzzy Logic Controller (FLC) and to analyze the system control using Matlab. The Fuzzy Logic Controller which is in three-stage processes, such as; i. Fuzzification is the process input data received by the fuzzy controller are translated into fuzzy sets, it. ii. Defuzzification which reconverts the fuzzy sets back to a crisp data which the output devices can understand and iii. Inference system (the Google machine) where the gathering and analyses of data and drawing of conclusions take place, About 90-99% of industrial controllers are using Proportional integral and Derivative (PID) controller which produce substandard cement/clinker as a result of its non-linarites. (Over burning/under burning). For this, fuzzy logic controller was used in this work, via a method of heat transfer system, to replace the conventional classical PID controller to produce quality cement/clinker. Unlike the PID, which produced overshoot and undershoot in its controllability, the FLC has zero overshoot and undershoot, since accurate production parameters are available for control. This leads to easy control and also, the production time, cost of production will be drastically reduced compared to when PID controller is being used to run the system.***

***Indexed Terms- Fuzzy Logic; Fuzzification; Defuzzification; Inference System; Overshoot; Undershhot.***

## I. INTRODUCTION

Cement being the final product of a cement factory, is gotten from the final output of the kiln called clinker. Producing the clinker with high quality leads to efficiency improvement in energy consuming, input material, and final benefit of the factory. These are all achievable by deploying a desirable and appropriate kiln controller. Producing neither over burning nor under-burning clinker is acceptable for a rotary kiln. Some factors such as flame shape, secondary air temperature, ID fan speed and etc all have considerable effects of the clinker quality. Most of the worldwide cement factories are being controlled by the direct knowledge of the expert kiln operators. Therefore, having the accurate knowledge of the situation and the states of the burning zone is critical for a kiln operator.

Cement production is a complex process, composed of a series of activities requiring substantial technological support. The basic process in a cement production plant is baking of the raw material mix in kiln (a long cylindrical complex tunnel). Cement kiln exhibits time varying nonlinear behavior which both physical and chemical reactions occurred in the kiln have complicated its dynamic equations. The corresponding equations have not been derived completely and accurately while a lot of present variables are discarded in the equations (Noshirvani, 2005). It is obvious that this fact may cause some problems in designing the controller for rotary kiln.

The majority of industrial controllers operating today are PID (Proportional-Integral- Derivative) controller. The use of these get to the point that much authors say that they occupy between 90% to 99% of an industrial process control (Algreer, 2008). Some factors that allow the widespread use of PID controllers are; the PID controllers are robust and easy to design, there is a clear relationship between the parameters of PID controller and the control response, and there are many techniques of tuning to facilitate the work. Despite this, the PID controllers are not the best solution to all control processes. In very complex processes with nonlinearities, time varying parameters and delays in the process, that are difficult to model analytically, the response of the PID is really very poor. In these cases the control classic methodology can simplify the model of the part but did not get good performance. For this cause, human constant supervision of the process is required, coupled with the fact that the human control is vulnerable to mistakes and is very dependent on experience and qualifications of the operator.

To this end, Fuzzy logic controller (FLC) is developed in this work, to override the effect of the PID control system and give a better controller option in the kiln temperature control. They are converting the error between the measured or controlled variable and the reference variable, into a command, which is applied to the actuator of a process. In practical design it is important to have information about their equivalent input-output transfer characteristics.

## II. OVERVIEW OF LITERATURE

Fuzzy controller of cement kilns has been one of the first successful applications of the fuzzy control in industry. In 1978, Holmblad and Ostergaard used the first fuzzy controller for a complex industry process, cement kiln. They saw that the results were much better than when the kiln was directly controlled by human (Wang, 1994). Nowadays, the cases of using the fuzzy logic controllers for controlling the cement kilns have been increased. This is based on this fact that the fuzzy logic controllers do not need an accurate model of the plant. By fuzzy logic controller, a remarkable improvement of the cement quality and a decline in the production expenses has been achieved. Several designs of such controllers have been proposed and/or implemented in (Devedzic, 1995), which have been designed based on the knowledge of the operators. There is also a practical description about the industrial concepts of Onoda's Cement Plant in (Aizawa, 1992). Image processing has been proposed as a solution to control a cement kiln in (Jing et al, 1997).

Fuzzy logic is a control system that deals with the vagueness intrinsic to human thinking and natural language. Fuzzy logic was first proposed by Lofti A. Zadeh of the University of California at Berkeley in a 1965 paper. He elaborated on his ideas in a 1973 paper that introduced the concept of "linguistic variables" (Zadeh, 1973), which in this article equates to a variable defined as a fuzzy set. In 1974, fuzzy set was successfully applied to an industrial control of cement kilns (Mamdani and Assilian, 1975). Pressure control was first used in this set-up to control the pressure in the cooler of that industrial machine. In this set up, pressure control was carried out by a sensor, which senses the pressure in the cooler, and then use the variable to control the process.

Hellendoorn. (1993) present a fuzzy self-tuning PID control scheme for controlling industrial processes. The essential idea of the scheme is to parameterize the well-known Ziegler-Nichols tuning formula by a single parameter $\alpha$ and then to use an on-line fuzzy inference mechanism to self-tune this parameter. The fuzzy tuning mechanism, with process output error and change of error as inputs, adjusts $\alpha$ in such a way that it speeds up the convergence of the process output to a set point and slows down the divergence trend of the output from the set point.

A connection between cause and effect, or a condition and a consequence is made by reasoning. Reasoning can be expressed by a logical inference or by the evaluation of inputs in order to draw a conclusion. We usually follow rules of inference which have the form: IF causel- A and cause2 B THEN effect C. Where A. B and C are linguistic variables. For example, IF "room temperature" is Medium THEN "set fan speed to Fast Medium is a function defining degrees of room temperature while Fast is a function defining degrees of speed. The intelligence lies in associating those two terms by means of an inference expressed in heuristic IF...THEN terms. In order to convert a linguistic term into a computational framework one needs to use the fundamentals of set theory. On the statement IF "room temperature" is Medium, we have to ask the following question "Is the room temperature Medium"? A traditional logic, also called Boolean logic, would have two answers: YES and NO. Therefore, the idea of membership of an elementx in a set A is a function uA(x) whose value indicates if that element belongs to the set A. Boolean logic would indicate, for example: A(x) = 1, then the element belongs to set A. or A(x) = 0, the element does not belong to set A.

### 2.3. Fuzzy Sets

Fuzziness means vagueness. Fuzzy set theory is an excellent tool to handle the uncertainty arising due to vagueness. Fuzzy logic control system is better than the PID control system in terms of robustness and less sensitiveness to parameter variations Fuzzy control consists of an input stage, a processing stage and an output stage. In crisp set the values are either full or none that is either 1 or 0. Whereas a fuzzy set supports many degrees of membership between 0 and 1. Fuzzy logic design is not based on the mathematical model of the process. The fuzzy controllers designed using fuzzy logic implements human reasoning that has been programmed into membership functions, fuzzy rules and rule interpretation. The fuzzy logic controller comprises of three fundamental processes, these are; Fuzzification, Inference process (decision maker and the knowledge base) and the defuzzification process. The structure of the fuzzy logic system is shown in Figure 2.1.

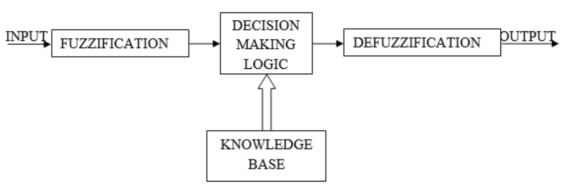


Fig 2.1: Structure of a Fuzzy Controller

- Design Method Analysis

Fuzzy control systems are model-free estimators, Fuzzy experts like LoftiZadeh, 1965 described fuzzy logic as a method of dealing with imprecision of practical systems. The design of a fuzzy logic controller is a three stage processes. It comprises of fuzzification. inference mechanism and defuzzification.

For the simulation process, a Graphic User Interface (GUI) of matlab was used.This research work is carried out on Fuzzy logic controller scheme for rotary cement kiln. The system is an intelligent- type controller, which based its actions on the If....Then rules. This is aimed at curbing the shortcomings experienced by the conventional PID systems, so as to improve the system output performance.

- Fuzzy Logic Algorithm

The following fuzzy algorithm was developed for this work:

i. Input determination and customization
ii. Output determination and customization
iii. iii.Fuzzy membership degree determination
iv. Development of the rule base
v. Allocation of the rule strength
vi. Rule combination
vii. Defuzzification

- 2nd Order Transfer Function of Kiln

The transfer function for the kiln is a second order type which is represented below:

$$H_p = \frac{Aw^2}{S^2 + 2\tau ws + w^2}$$

A = gain
w=the resonant, or natural frequency of oscillation in rad/sec
ζ=the damping coefficient [Range: 0 to 1]

- Mamdani Fuzzy Inference System

As stated in the algorithm for this work above, the fuzzy inference system is set up hereunder (Figure 3.1):

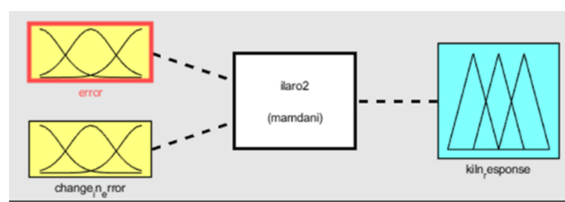


Figure 3.1: Mamdani Fuzzy Inference System

The membership function fir the system is as shown in Figure 3.2

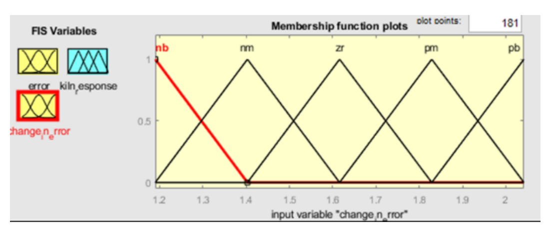


Figure 3.2: The Membership Function

The PID compensator configuration used for the kiln control is given by:

$$P + I\frac{1}{S} + D\frac{N}{1 + N\frac{1}{s}}$$

Where the initial value of P = 1, I = 1, N = 100, D = 0


Figure 3.3: The PID configuration for the kiln control

## III. RESULT AND DISCUSSION

### 4.1 Results

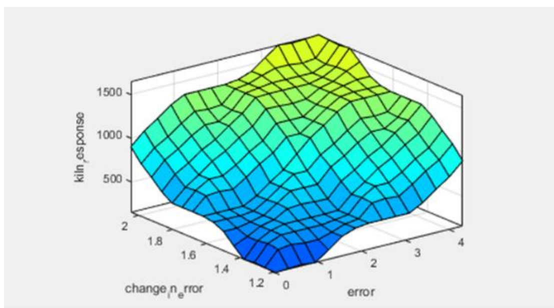


Figure 4.1: Surface of the rule base

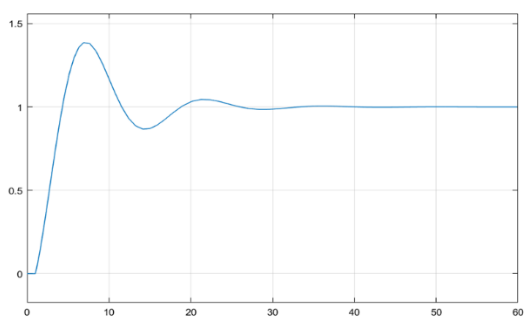


Figure 4.2: PID Response to Temperature Change

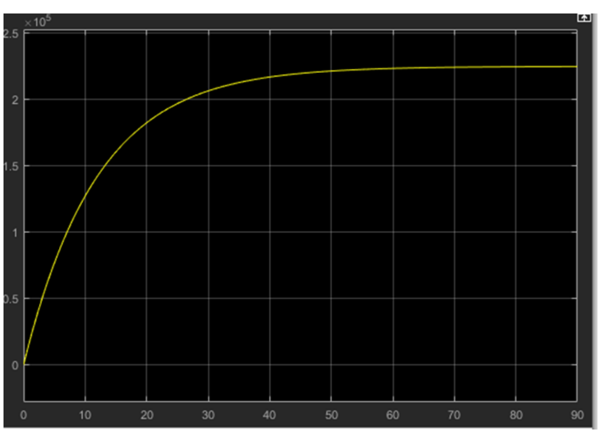


Figure 4.3: Fuzzy controller-based kiln response

Figure 4.1: Surface of the rule base
Figure 4.2: PID controller-based kiln response
Figure 4.3: Fuzzy controller-based kiln response

### 4.2 Discussions

Figure 4.1 shows the surface view, which the relationship between the two inputs and the output for each of the PID parameters.

In figure 4.1 shows the PID control of the kiln temperature, here, the temperature control in the kiln could not be ascertain due to the overshoots and undershoots ii the system control. This leads to a high energy being consumed in the production system, which means more cost in terms of production.

Figure 4.3 shows the relationship between the FLC and the kiln. It could be seen that the signal picks at rise time and becomes stable with zero overshoot and undershoot, to show the efficiency of the control system over the PID, which gives evidence of overshoots and undershoots, giving low temperature control. But for the FLC, it gathers high efficiency with high level temperature control, to give low cost, low energy consumption and in all good temperature control.

## IV. CONCLUSION AND RECOMMENDATIONS

- Conclusion

Fuzzy logic controller for kiln control performs relatively well. It is well suited for analogue mode kiln system which makes it not directly "integrable with other expert systems. Fuzzy logic system could be used to replace the conventional classical PID controller which requires tuning by experienced personnel. It is an autonomous system and does not require the precise solution to full mathematical model of the system to be controlled unlike the PID controller.

- Recommendations

This work clearly shows numerous advantages of fuzzy logic-based controllers over the conventional PID based controllers and therefore, it is recommended that this controller (FLC) should be applied to rotary cement kiln operation for optimal performance and autonomous operation as appropriate kiln temperature control would lead to quality product and could bring down the production cost of Portland cement as input-output ratio is adequately maintained.

Although, in another dimension, the duo, FLC and PID could meshed for economic reason.

Contribution to Knowledge

The contribution to knowledge of this research work are:

- The cement product quality is improved as accurate production parameters are available for production.
- Production time and cost is reduced compared to when PID controller is used to run the system.

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